

Evaluation of corn and barley varieties in extensive winter grazing systems for beef calves

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ABSTRACT

Two experiments were conducted to determine the suitability of whole plant corn as an alternative forage to whole plant barley for winter grazing and the subsequent effect of extensive winter grazing systems on performance and carcass characteristics of beef steers during feedlot finishing. Experiment 1 evaluated the *in vitro* digestibility of dry matter (IVDMD) and neutral detergent fibre (IVNDFD) of whole plant corn (COR), whole plant barley (BAR) and processed barley hay (CON) collected on October and February sampling dates over 2 yrs. COR forage had similar ($P>0.05$) IVDMD and IVNDF to both CON or BAR forage. The IVDMD and IVNDFD also remained similar ($P>0.05$) between the October and February sampling date for COR and BAR forages and processed barley hay. Experiment 2 evaluated the effects of grazing either swathed whole plant barley, standing whole plant corn, or drylot fed barley hay on forage quality, estimated intake, calf performance and backgrounding production costs over 2 years. In each year, 120 spring born Angus calves (263.3 ± 5 kg; 169 d of age) were fall weaned, stratified by body weight and randomly allocated to 1 of 3 replicated ($n = 2$) backgrounding systems: 1) field grazing standing whole plant corn (COR); 2) field grazing swathed whole plant barley (BAR); or 3) dry lot (CON) bunk fed processed barley hay. Calves fed COR and BAR were limit grazed in 4-ha paddocks for a 3-d grazing period using electric fencing for an average of 97 d over 2 yr, with all calves receiving a pelleted supplement (78% TDN, 16% CP) daily at 0.8% BW. A randomized complete block design (RCBD) was used to analyze crop yield, crop quality, dry matter intake (DMI), body weight (BW), average daily gain (ADG), total system cost and cost of gain (COG) over the 2 yr trial. Forage samples were collected every 21 d to determine forage quality. Protein content was greater ($P<0.01$) for CON (11.1%) compared to BAR and COR forage (10.1 and 7.9%, respectively). Neutral detergent fibre was greater ($P=0.03$) for

BAR (63.3%) compared to CON (60.3%), while COR forage (62.9%) was not different ($P>0.05$) from either CON or BAR forage. Acid detergent fibre was not different ($P>0.05$) between the 3 forage types. Total digestible nutrients and net energy for gain were greater ($P<0.01$) for the COR forage (62.3% and 0.36 Mcal/d, respectively) compared to CON (57.8% and 0.30 Mcal/d, respectively) and BAR (59.0% and 0.32 Mcal/d, respectively). Calcium was greater ($P<0.01$) for CON and BAR (0.39 and 0.37%) compared to COR (0.20%) forage. Phosphorus content was greater ($P<0.01$) for CON (0.27%) then BAR (0.23%) and COR (0.20%) forage. There was no difference ($P>0.05$) in DMI, BW, ADG or COG between the 3 backgrounding systems. Total cost of production was greatest ($P<0.05$) for CON calves (\$2.57/calf/day) compared to COR and BAR calves (1.40 and 1.48 \$/calf/day). Net return was greatest for COR and BAR calves (65.03 and 61.60 \$/hd, respectively) compared to CON calves (\$-28.85/hd). After backgrounding, replicates of calves were divided into 2 groups and placed in a feedlot each year of the trial. Calves were fed a barley silage based diet with either barley or corn grain for 203 d to a weight of 667.8 ± 5 kg, at which point they were slaughtered and carcass data was collected. A RCBD split plot was used to analyze DMI, BW, ADG, dressing %, hot carcass weight (HCW), ribeye area, and marbling score while quality and yield grade data were analyzed using the GLIMMIX macro with a binomial error structure and logit data transformation. Dressing % was greatest for both COR and CON steers fed the corn grain diet (58.9%) and HCW was greatest ($P<0.05$) for COR steers fed a corn grain diet (397.5 kg). There was no difference ($P>0.05$) in BW, DMI, ADG, yield grade or carcass characteristics among systems, suggesting that backgrounding calves by field grazing either standing whole plant corn or swathed barley is a viable option to decrease winter feeding costs without having an effect on finishing performance.

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TABLE OF CONTENTS

PERMISSION TO USE	i
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	ix
LIST OF EQUATIONS	x
LIST OF ABBREVIATIONS	xi
1.0 General Introduction	1
2.0 Literature Review	2
2.1.1 Protein	2
2.1.2 Energy	4
2.1.3 Minerals and Vitamins	6
2.2 Backgrounding Systems	7
2.2.1 Intensive Backgrounding Systems	8
2.2.2 Extensive Backgrounding Systems	9
2.2.3 Cool Season Forages	10
2.2.4 Warm Season Forages	12

2.3 Extensive Beef Cattle Grazing Systems	14
2.3.1 Stockpiled Forage Grazing	14
2.3.2 Swath Grazing	15
2.3.3 Bale Grazing	16
2.4 Determining Dry Matter Intake.....	17
2.4.1 Monitor Systems.....	18
2.4.2 Herbage Disappearance Technique	19
2.4.3 Pasture Cage Comparison Technique	20
2.4.4 Indigestible Markers	21
2.5 Methods of Determining Forage Digestibility	22
2.5.1 In Situ and In Vivo	22
2.5.2 In Vitro	23
2.6 Estimation of Animal Performance.....	24
2.6.1 Body Weight and Condition Scoring.....	24
2.6.2 Body Fat Ultrasonography.....	25
2.6.3 Finished Carcass Composition	26
2.6.4 Residual Feed Intake	26
2.7 Effect of Background System on Feedlot Finishing	27
2.8 Summary of Literature Review	28

3.0 In vitro digestibility of corn and barley varieties collected at two calendar dates during a winter backgrounding trial	30
3.1 Introduction	30
3.2 Materials and Methods	30
3.2.1 Sample Collection.....	30
3.2.2 Weather Data	31
3.2.3 In Vitro Incubation	32
3.2.4 Calculations	33
3.2.5 Statistical Analysis	34
3.3 Results and Discussion.....	34
3.4 Conclusion.....	36
4.0 Evaluation of barley and corn varieties for extensive winter grazing systems for beef calves	37
4.1 Introduction	37
4.2 Materials and Methods	39
4.2.1 Site and Crop Management	39
4.2.2 Backgrounding Systems and Grazing Management.....	40
4.2.3 Weather Data	41
4.2.4 Laboratory Analysis	42
4.2.5 Calculations	43

4.2.6 System Cost Analysis	44
4.2.7 Feedlot Finishing Trial	44
4.2.8 Statistical Analysis	46
4.3 Results and Discussion	47
4.3.1 Forage Yield and Quality	47
4.3.2 Backgrounding Calf Performance	50
4.3.3 Backgrounding Cost Analysis	55
4.3.4 Steer Performance Feedlot Finishing	57
4.4 Conclusion	63
5.0 General Discussion and Conclusion	64
7.0 References.....	67
8.0 Appendices.....	78
8.1 Appendix A	78
8.2 Appendix B	80

LIST OF TABLES

Table 2.1 Chemical composition of cool season perennial grass species in fall/winter grazing programs (% DM)	11
Table 2.2 Chemical composition of cool season annual forages for winter grazing (% DM)	12
Table 3.1 In vitro digestibility (%) of three forages collected at 2 sampling dates over 2 yr	35
Table 4.1 Forage DM yield and chemical composition of forages in backgrounding systems over 2 yr, (DM basis)	49
Table 4.2 Effect of backgrounding system on dry matter intake (DMI) and beef calf performance over 2 yr	53
Table 4.3 Cost analysis of backgrounding systems over 2 yr	56
Table 4.4 Revenue analysis of backgrounding systems over 2 yr	57
Table 4.5 Ingredient list and chemical composition of feedlot total mixed ration over 2 yr	58
Table 4.6 Effect of backgrounding system and grain type in finishing diet on steer feedlot performance over 2 yr	60
Table 4.7 Effect of backgrounding system and finishing diet on carcass grading	61

LIST OF EQUATIONS

Equation 3.1 <i>In vitro</i> dry matter digestibility (Damiran et al., 2008).....	32
Equation 3.2 Neutral detergent fibre digestibility (Cook and Stubbendieck, 1983).....	33
Equation 4.1 Total digestible nutrients (Weiss et al., 1992).....	42
Equation 4.2 Dry matter intake (Jasmer and Holechek, 1984).....	43

LIST OF ABBREVIATIONS

ADF	Acid detergent fibre
ADG	Average daily gain
ADIN	Acid detergent insoluble nitrogen
BAR	Field grazing treatment using whole plant barley forage
BCS	Body condition score
BF	Back fat
BW	Body weight
Ca	Calcium
CHU	Corn heat unit
COG	Cost of gain
CON	Control drylot treatment using processed barley hay
COR	Field grazing treatment using whole plant corn forage
CP	Crude protein
CPD	Crude protein digestibility
Cr ₂ O ₃	Chromic oxide
d	Day

DCP	Digestible crude protein
DIP	Digestible intake protein
DM	Dry matter
DMI	Dry matter intake
DMD	Dry matter digestibility
DMY	Dry matter yield
FBW	Final body weight
h	Hour
ha	Hectare
hd	Head
He	Heat production
HCW	Hot carcass weight
IBW	Initial body weight
IVDMD	<i>In vitro</i> dry matter digestibility
IVNDFD	<i>In vitro</i> neutral detergent fibre digestibility
kg	Kilogram
LCT	Lower critical temperature

Lig	Lignin
MP	Metabolizable protein
mL	Millilitres
NEg	Net energy of gain
NE _m	Net energy of maintenance
NDF	Neutral detergent fibre
NDIN	Neutral detergent insoluble nitrogen
NH ₃	Ammonia
NPG	Net pasture growth
NPN	Non-protein nitrogen
NSC	Non-structural carbohydrates
OM	Organic matter
OMD	Organic matter digestibility
P	Phosphorus
RCBD	Randomized complete block design
RDP	Rumen degradable protein
REA	Rib eye area

RFI	Residual feed intake
SAS	Statistical analysis systems
SC	Structural carbohydrates
TDN	Total digestible nutrients
yr	Year
Yb	Ytterbium
%	Percentage

1.0 General Introduction

It is estimated that forage occupies 80% of the feed required to feed beef cattle in Canada (Statistics Canada, 2014), which represents ~60% of total feed costs (Kaliel and Kotowich, 2002). In addition, intensive feeding programs where cattle are housed in pens are known to have greater costs than extensive grazing programs (McCartney et al., 2004; Anderson and Boyle, 2007; Mathis et al., 2007). Extensive grazing in western Canada has gained popularity due to the ability to reduce costs for wintering both dry, pregnant beef cows and weaned beef calves in a backgrounding program (Kelln et al., 2011; Kumar et al., 2012). Winter feeding costs can be reduced by up to 50% using extensive grazing systems due to decreased labor, time and equipment costs (Volesky et al., 2002; McCartney et al., 2004). Annual cereals and perennial grasses have been used successfully for grazing cattle with new interest in the use of low heat unit corn varieties (Klopfenstein et al., 1987; McCartney et al., 2004; Mathis et al., 2007). Whole plant corn has been shown to have similar or greater digestibility, energy and protein content, and yield potential to other annual cereals such as barley (Lardner, 2004; May et al., 2007; McCartney et al., 2008). Weaned calves that are backgrounded on extensive winter grazing systems have been shown to gain similarly to calves fed in drylot pens, with no significant impact on final feedlot finishing performance (Vaage et al., 1998; Kumar et al., 2012). This review evaluates the literature in an effort to compare backgrounding systems for beef calves and the subsequent effect on feedlot performance. The objectives of this review are to (i) evaluate beef calf nutrition and nutrient requirements with respect to backgrounding and finishing programs, (ii) compare different extensive and intensive beef calf backgrounding programs, (iii) discuss methods of determining forage yield, nutritive value, and estimated intake, and (iv) discuss methods of determining beef cattle performance.

2.0 Literature Review

2.1 Nutritional Requirements for Growing Beef Cattle

When considering a beef cattle backgrounding program, the type of forage to be used must be carefully evaluated as forage quality is an important aspect in terms of meeting the nutrient requirements of grazing cattle. The National Research Council (2000) states that the protein and energy requirements for a 250 kg weaned calf targeted to gain 0.8 kg/day are 9.8% crude protein (CP) and 60% total digestible nutrients (TDN). It is also stated that maintenance energy (NEm) requirements increase 10 to 20% for grazing animals compared to drylot fed animals (NRC, 2000). To determine forage quality, a representative sample should be taken from the pasture shortly before grazing starts (AAFRD, 1998). The laboratory analysis results will provide information to determine if the primary forages are adequate in providing required nutrients for targeted gain or if supplementation will be needed. Forage Crop Production Guides can also be used to assist with the forage selection process as they provide a range of nutrient values for various forages (Saskatchewan Ministry of Agriculture, 2015; Saskatchewan Forage Council, 2015). In addition to forage, several studies have shown that a protein and/or energy supplement can increase daily intake and body weight gains when provided to cattle grazing low to moderate quality forage (Van Soest, 1994; Jung and Allen, 1995; Bodine and Purvis, 2003).

2.1.1 Protein

Ruminants are unique in that metabolizable protein (MP) can come from 3 different sources; feed protein, microbial protein or endogenous protein (NRC, 2000). Feed protein refers to rumen degradable protein (RDP) and amino acid content of the diet fed to the animal (Van Soest, 1994). Jung and Allen (1995) reported that forage fiber didn't affect RDP, however,

deleterious factors in forages (such as tannins and lignin content) and artificial drying of the feed can reduce digestible crude protein. Once feed particles containing feed protein have reached the rumen, they are degraded to amino acids and ammonia (NH_3), where rumen microbes use the amino acids for microbial colony growth (Lalatendu et al., 2014). A proportion of the microbial population then passes to the small intestine where they are digested and absorbed by the ruminant's lower tract, thus providing a second source of crude protein. Van Soest (1994) explains that ruminants can receive anywhere from 50% to almost all the MP requirement from this microbial protein source. The third source is endogenous protein which is sloughed epithelial cells from the walls of the upper digestive tract, which are then digested in the small intestine (Van Soest, 1994).

A variety of feed sources are available to use as protein supplements such as high quality forages (alfalfa), oilseed by-products, rumen undegradable protein (bypass protein) and non-protein nitrogen (NPN) sources (urea) (NRC, 2000). It has been suggested that a supplement should be provided to cattle when the CP level of the forage is below 6 to 8 percent (NRC, 2000). Overall, protein supplementation is beneficial when grazing high fibre, low quality forages and is often needed for successful grazing (Bodine and Purvis, 2003). It is important to note that supplementation can cause substitution effects where cattle selectively eat one component of the diet over the other, thus altering cattle grazing behavior (Bodine and Purvis, 2003). Bowman and Sanson (1996) have shown that when cattle are supplemented over maintenance requirements, a positive substitution effect can occur, generally 1 kg of forage intake decreases per 1 kg of supplement intake, but it is important to note that the substitution rate will differ based on the type of supplement. Krysl and Hess (1993) provided a protein supplement to cattle grazing average quality forage and found that non-supplemented cattle

grazed 1.5 h per d longer than supplemented cattle. However, rumen microbes require rumen degradable protein (RDP) for amino acids and peptides synthesis. If RDP is insufficient and microbial activity is suppressed, intake will decrease as a result (Bodine and Purvis, 2003; Lalatendu et al., 2014).

2.1.2 Energy

Cattle maintain constant body temperature by either heat production through tissue metabolism and digestive tract fermentation, or by heat dissipation (Young, 1983). In the thermal neutral zone, heat production (HE) is independent of environmental temperatures (Van Soest, 1994). In western Canada, cattle grazing during the winter are exposed to wind chill factors and cold temperatures which fall below the zone of thermoneutrality. This can also be referred to as the lower critical temperature (LCT) in which animals will experience bouts of cold stress (Van Soest, 1994). During these times, it is important to determine if the forage alone can meet the energy demands of the animal and possibly consider the use of an energy supplement. With respect to growing beef cattle, net energy for maintenance (NEm) and growth (NEg) are important values to keep in mind (NRC, 2000). Net energy maintenance represents the ability of a feed to meet the primary energy requirements for maintenance and NEg represents the ability of a feed to meet the energy requirements for growth (Van Soest, 1994). It is stated that a 250 kg growing calf requires 4.84 Mcal/d for maintenance and 3.21 Mcal/d to gain 1.0 kg per day (NRC, 2000).

Energy supplements usually consist of either non-structural carbohydrates (NSC) or structural carbohydrates (SC) (Winger et al., 2006). Non-structural carbohydrates containing starch and sugars have a short retention time in the rumen and are easily digested (Lardy et al.,

2004). Some common feeds which contain NSC's include corn, barley, oat grain, and molasses based liquids. Past research has shown that grazing cattle supplemented with less than 23% corn grain (Henning et al. 1990) or less than 12.5% barley grain (Lardy et al., 2004) of their total diet resulted in increased total intake. While NSC's provide energy quickly to the animal, they are also known to have the potential to decrease ruminal pH, which can have a significant impact on digestibility and microbial activity (Winger et al., 2006). Caton and Dhuyvetter (1997) support the theory that decreased pH causes a shift from cellulolytic bacteria to amylolytic bacteria which in turn causes decreased fiber digestibility and possibly decreased dry matter intake (DMI). Bowman and Sanson (1996) also found that NSC supplementation can lead to positive substitution effects in high fiber diets where forage intake decreases due to supplementation. It is recommended that corn grain be supplemented at <0.25% BW and barley grain at <0.8% BW to minimize any adverse effects on DMI (Matejovsky and Sason, 1995; Henning et al., 1990). In contrast, structural carbohydrates (SC) contain cellulose and hemicellulose and are digested slower than NSC feeds, which minimize risk for disturbances in rumen pH and microbial activity (Bowman and Sanson, 1996). Common feeds containing SC are soybean hulls, wheat middlings, and beet pulp. Generally, SC sources will not affect the digestibility of forages, however, the MP of a diet is still an important factor when considering supplements.

Energy content of mature forages can often be too low to meet the requirements for growing cattle managed in winter grazing systems, and this deficiency in energy may reduce rumen passage rate and microbial efficiency (Lardy et al., 2004). However, low intake of a high energy diet can actually maximize microbial efficiency (Bodine and Purvis, 2003). When grazing low quality forages, research has shown that high energy supplementation will not result in increased gains in grazing cattle and will in fact decrease DMI as RDP isn't sufficient for

microbial activity (Bodine and Purvis, 2003; Lardy et al., 2004). Poore and Drewnoski (2010) reported that cattle responded to energy supplementations when pasture forage CP was greater than 12%, and an even greater response can be seen when forage CP was greater than 14 percent. A NPN source can also be added to the high energy diet to counteract this issue of insufficient RDP in the diet (Caton and Dhuyvetter, 1997). Van Soest (1994) reported that 13 g of microbial protein is synthesized for every 100 g of TDN in the diet, indicating the relationship between protein and energy requirements.

2.1.3 Minerals and Vitamins

Mineral and vitamin requirements of growing beef cattle should also be considered when managing animals in an extensive winter grazing system. Calcium (Ca) is an important mineral due to its vital role in numerous body functions such as muscle contraction, nerve impulse transmission, membrane permeability, and blood clot factors (NRC, 2000). The true Ca requirements of a beef animal for maintenance have been estimated to be 15.4 mg Ca/kg of body weight (Hansard et al., 1957). Since the absorption of Ca is 50% of intake, true Ca requirements are converted to dietary Ca requirements, therefore a 250 kg growing calf targeted to gain 1.0 kg/d would require 25.0 grams per day (NRC, 2000).

Phosphorus (P) is also an important mineral for beef cattle due its functions in cell membrane growth and differentiation, cell acid/base regulation, and rumen microbial growth. The true P requirements for maintenance have been calculated to be 16.0 mg P/kg of body weight (NRC, 2000) but absorption of P has been assumed to be only 68% of total intake (Martz et al., 1990). The dietary requirements for a 250 kg growing calf targeted to gain 1.0 kg/d would require 10

grams per day (NRC, 2000). Since Ca and P interact with each other in bone formation, it has been recommended that cattle be fed at a Ca:P ratio ranging between 1:1 and 7:1 (NRC, 2000).

Vitamin A has been recognized as being the most important practical vitamin in growing cattle due to its role in growth and bone development (NRC, 2000). It is derived by body tissues in the presence of the plant synthesized precursors carotene and carotenoid (NRC, 2000). The requirement for feeder cattle (including growing steer calves) is 2,200 IU/kg of dry matter (NRC, 2000). A deficiency in this vitamin is most likely caused from forages which were grown during drought conditions or when forages were exposed to high temperatures and direct sunlight (NRC, 2000).

2.2 Backgrounding Systems

In the beef cattle industry, there is an opportunity for producers to retain ownership of weaned calves and feed them through the winter until they are a targeted weight to market as yearlings (Drouillard and Kuhl, 1999). The term ‘backgrounding’ refers to weaned beef calves which are grown at a targeted rate of gain of ~0.7 kg/d so that the skeletal frame size can increase with only minimal fat deposition (Perrillat et al., 2003). In western Canada, beef calves are typically weaned around 200 to 250 kg BW and are then backgrounded for 100 to 150 d until they reach 350 kg (Karantininis et al. 1997). Karantininis et al. (1997) explained that over the past 20 years backgrounding has opened more options for marketing feeder cattle. Research by Waggoner et al. (2005) and Mathis et al. (2007) reported that feedlots have found it profitable to purchase backgrounded yearling cattle because these cattle already have a large carcass frame and can be finished in half the number of days on feed compared to calves entering the feedlot as calf feds. The authors also found that the value of backgrounded cattle was found to increase

during the finishing phase (Waggoner et al. 2005; Mathis et al. 2007). There are several options for different types of backgrounding systems managed during the winter months.

2.2.1 Intensive Backgrounding Systems

Drylot feeding systems are common on beef cattle farms in western Canada during the winter months, similar to traditional feedlot systems. Drylot systems can be used successfully in a backgrounding program, but also have increased costs and therefore the cost of gain (COG) for wintering calves would be increased when compared to calves extensively grazed (Anderson and Boyles, 2007). The COG illustrates the total cost to add weight on an animal and includes purchase price, transportation, feed delivery, labor, manure removal, mechanical equipment and infrastructure. Kumar et al. (2012) reported that COG was 31% less for calves grazing swathed whole plant barley compared to feeding in drylot pens, and the total cost of production was 49% higher for drylot fed calves. There is also evidence that calves backgrounded in drylot pens may have increased health risk compared to those backgrounded on extensive grazing systems (Mathis et al., 2007). Mathis et al. (2007) compared high-input drylot systems to backgrounding systems and found that steers at drylot system had a greater death loss and likely had suppressed immune function leading to an increased number of animal health treatments. When cattle are being treated for an illness, net profits will decrease as shown by Brooks et al. (2011). Brooks et al. (2011) found a linear decrease in profit with each treatment required during backgrounding; cattle that were not treated had a net return of \$111.12/head and cattle that were treated more than 3 times had a net return of only \$20.62 per head. Cattle that were treated more than 3 times also required longer days on feed to reach weights similar to those that were untreated or treated only 1 or 2 times, therefore increasing feed and yardage costs (Brooks et al., 2011).

2.2.2 Extensive Backgrounding Systems

Backgrounding systems utilizing a winter grazing system have become an area of interest for both researchers and producers due to benefits from low COG, decreased animal health issues, and overall profitability (Lardner, 2004; McCartney et al., 2004; Mathis et al., 2007; Kumar et al., 2012). Winter grazing has the potential to lower costs associated with winter feeding such as manure removal, maintenance of fencing and windbreaks, labor, and feed, while still maintaining adequate animal performance (Kumar et al., 2012). Since western Canada has a large percentage of farm land that can support the growth of high yielding crops, the ability to successfully winter graze cattle is attainable. There are many different winter grazing systems available, including bale grazing, stock piled forage grazing, crop residue grazing and swath grazing (Klopfenstein et al., 1987; McCartney et al., 2004; Kelln et al., 2011; Kumar et al., 2012). These grazing strategies are practiced throughout the western United States for managing cow-calf pairs, dry pregnant beef cows, and feeder cattle (Klopfenstein et al., 1987; Adams et al., 1994; Hitz and Russel, 1998). In western Canada, due to the cold winter weather, these extensive systems are most often used for wintering the beef cow with the goal of maintaining body condition (McCartney et al., 2004; Kelln et al., 2011). However, the potential to reduce backgrounding costs has initiated research evaluating winter grazing programs for growing beef calves (Kumar et al., 2012). Mathis et al. (2007) compared low-input pasture grazing systems to high-input drylot systems over 45 d and found that the pasture system was more profitable (\$44.59/hd greater for pasture managed calves) during the backgrounding period. These researchers also found that pasture backgrounded steers earned a high net income following finishing at the feedlot due to greater carcass weight and price, and minimal treatment for illness (Mathis et al., 2007). Morbidity (sickness requiring treatment) and mortality (death loss) has

also been shown to be decreased during the feedlot phase when steers were from either a grazing backgrounding system or preconditioning program (Roeber et al., 2004; Mathis., 2007). Roeber et al. (2004) stated that the cost of medicine and extra labor needed to deal with sick animals can have a major impact on overall profitability. The author's compared animal health issues from 2 different preconditioning programs to a control group of steers bought at an auction mart with no previous preconditioning treatment. The research found that morbidity rates for the 2 preconditioned groups were lower (34.7 and 36.7%, respectively) than the control group (77.3%) suggesting that preconditioning does improve overall health of the feedlot animal (Roeber et al., 2004).

2.2.3 Cool Season Forages

Cool season forages include 2 groups, cool season perennial grasses and cool season annuals cereals. These forages are most commonly used for beef cattle grazing in western Canada because they are well suited to the climatic conditions and provide acceptable forage yields and nutritional quality (May et al., 2007).

Cool season perennial grass species can be either native or tame, and include different species of brome grasses (*Bromus spp.*), fescues (*Festuca spp.*), wheat grasses (*Agropyrum spp.*), and ryegrasses (*Lolium L.*). These grass types typically begin growth mid-April once the soil temperature at seed depth reaches 5°C with the optimum temperature for growth of 18 to 24°C (Fransen and Griggs, 2002). Crested wheatgrass [(*Agropyron cristatum (L.)*)] and smooth brome grass (*Bromus inermis* Leyss.) are recommended for early spring grazing in western Canada because of early growth potential and high forage quality, which allow grazing steers to gain between 0.9 to 1.6 kg/d (Williams and Post, 1945; Hoffman et al., 1993; Anez-Osuna et al.,

2015) (Table 2.1). However, these two forage grass species are not ideal for late summer or fall grazing as they lose quality and re-growth can be slow, therefore forage mixtures including meadow brome grass (*Bromus biebersteinii*) has been suggested due to its excellent re-growth potential (Hart et al., 1988).

Table 2.1 Chemical composition of cool season perennial grass species in fall/winter grazing programs (% DM)

Forage ²	Item ¹		
	CP	NDF	ADF
Crested Wheatgrass	11	65	36
Smooth Brome grass	11	64	36
Meadow Brome grass	9	60	35
Tall Fescue	9	61	35

Adapted from Lardner et al., 2013

¹CP = Crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre

²Forages sampled at a late grazing period from Aug 23 to Sept 7

Cool season annual cereals include barley (*Hordeum vulgare* L.), oat (*Avena sativa*), wheat (*Triticum* L.), rye (*Secale cereal*), and triticale (*Triticosecale*) (Table 2.2). If these crops are used for a winter grazing system, it is recommended they be seeded mid-June so that harvesting (swathing) can occur around late-August to help ensure the crop has not reached full maturity (McCartney et al, 2008; Baron et al., 2012). Previous research by Kumar et al. (2012) has shown that beef calf performance can be enhanced when winter grazing whole plant barley swaths in field paddocks. The study reported that calves grazing whole plant barley gained 32% more than calves grazing millet swaths and had similar performance to drylot bunk-fed calves (Kumar et al., 2012). McCartney et al. (2008) found that whole plant barley had greater DM digestibility and CP content compared to whole plant oat. The use of a cool season cereal compared to native range may also be advantageous, as shown by Choat et al. (2003) where

calves grazing swathed wheat in field paddocks had greater ADG (1.03 vs 0.29 kg/d) and final BW (412 vs 280 kg) than calves grazing native pasture on rangeland.

Table 2.2 Chemical composition of cool season annual forages for winter grazing (% DM)

Forage ²	Item ¹			Reference
	CP	NDF	ADF	
Barley	11	57	32	May et al., 2007
Oat	11	56	33	May et al., 2007
Rye	8	53	30	AAFRD, 2005
Triticale	10	48	29	AAFRD, 2005

¹CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre

²Forages sampled at soft dough stage

2.2.4 Warm Season Forages

Warm season forages such as millet have been used for winter grazing in western Canada (May et al., 2007; Kumar et al., 2012). Lardner et al. (2011) also compared red proso millet (*Panicum miliaceum*) to oats and found them to have similar CP (11.0 and 10.0%, respectively) and TDN (60.9 and 57.6%, respectively) values. Previous work by Kumar et al. (2012) reported that grazing whole plant foxtail millet (*Setaria italica*) with a nutritive value of 13.8% CP and 57.3% TDN, can be an acceptable choice for growing beef calves. However, calf performance when grazing whole plant foxtail millet was less than calves grazing whole plant barley (0.6 vs 0.8 kg/d ADG and 269.4 vs 288.1 kg final BW, respectively) (Kumar et al., 2012). Lardner et al. (2008) suggested that Golden German millet can be a suitable annual forage for grazing due to high biomass yields and nutritional quality (14% CP and 60% TDN). However, the authors reported that beef calves grazing Golden German millet gained 1.3 kg/d, which was lower than

calves grazing either swathed barley or fed a processed hay ration in drylot pens (1.9 and 1.6 kg/d, respectively). The work by Kumar et al (2012) and Lardner et al (2008) suggest that even though whole plant foxtail and Golden German millet provide nutrients similar to cool season forages, ADG remains lower in backgrounding calves.

Whole plant corn (*Zea mays* L.) is another warm season forage option, but has predominantly been grown in western Canada for grain and silage production. Due to the introduction of low heat unit varieties, the use of corn as an annual crop for winter grazing has become an area of interest (Lardner, 2004). McCartney et al. (2009) reported that a corn heat unit (CHU) is how much heat is accumulated over a growing season from May 15 to the first day of killing frost in the fall. McCartney et al. (2009) suggested that 2000-2100 CHU's were needed for successful corn growth in the western Canadian provinces. On average, the quality of low CHU corn varieties contain 7.8% CP and 69.7% TDN, and would easily meet the energy requirements of a growing beef calf (Lardner et al., 2012). The nutrient composition of corn also varies between the plant structures. Lardner and Larson (2012) compared the energy and protein composition of the whole plant corn plant, leaves and cob (plus grain) from 5 different varieties. The authors found on average TDN of the whole plant was 69.4%, leaves 57.1% and cob 90.1% while CP of the whole plant was 7.4%, leaves 11.8% and cob 11.7% (Lardner and Larson, 2012).

When comparing dry matter yield (DMY) of warm and cool season forages, the DMY of warm season annuals often are reduced when weather conditions are not favorable, as shown with research by May et al. (2007). The authors compared 2 yr of warm and cool season annual crop yields (May to August), where yr 1 was warmer than yr 2 (16 vs 12.5°C, respectively). All the warm season annuals (millet, sorghum, and corn) were outyielded by barley and oat in yr 2 under the cooler temperature (May et al., 2007). However, in yr 1, corn outyielded both barley

and oat (8.3 vs 6.8 and 6.0 t/ha, respectively) (May et al., 2007). Baron et al. (2014) confirmed that cows grazing corn in central Alberta had higher gains than cows grazing swathed barley, due to the higher nutrient density and yield of the corn crop. Early work by Lardner (2004) used whole plant corn and barley to winter graze backgrounded beef calves and found that corn (10.8% CP, 71.7% TDN), yielded 2.29 t/ha, and calves gained 0.68 kg/d while barley (14.8% CP, 69.9% TDN), yielded 0.75 t/ha, and calves gained 0.45 kg/day. The work by Lardner et al. (2004) and Baron et al. (2014) strongly suggest that whole plant corn could be a very good alternative option compared to whole plant barley for extensive grazing systems in western Canada.

2.3 Extensive Beef Cattle Grazing Systems

2.3.1 Stockpiled Forage Grazing

Stockpiling forage refers to the accumulation of forage biomass in the field until grazing, either in the fall or winter, or during a time when feed availability has been compromised (Poore and Drewnoski, 2010). The idea of making cattle travel to their feed instead of delivering the feed to them has been an economically wise strategy and has also been utilized in winter grazing systems (McCartney et al., 2008; Kumar et al., 2012). In Canada, producers have relied on the use of cool season perennial and annual forages. McCartney et al. (2008) suggests that annual cereals can be an advantageous option for fall and winter grazing. The planting dates of annuals meant for stockpiled grazing are flexible enough that peak yields can be timed to occur after the peak yield of a perennial forage (where 60% of production occurs before July 1 in western Canada). As forages mature, the stem becomes more fibrous causing a decrease in dry matter digestibility (DMD) and CP content (Jung and Allen, 1995; Johnson et al., 1999; Burns and

Chamblee, 2000). After the October freeze period in Western Canada, leaching of plant cell solubles from precipitation and snowmelt can occur, reducing digestible DM yield and increasing cell wall fibre (Kilcher, 1981; Volesky et al. 2002; Aasen et al. 2004). Senescence of the leaves will also occur, causing defoliation and an additional loss of nutrients (Kilcher and Troelsen, 1972; Kilcher and Heinrichs, 1974). Volesky et al. (2002) compared the nutritional quality of standing cool season grasses at different sampling dates and found that CP content was the limiting nutrient, declining 5.7% from September to February. However, the starch content of annual cereals has been shown to increase with advancing maturity due to grain kernel formation, therefore increasing the available energy (Baron et al., 2012). A study by Kulathunga et al. (2014), compared cows grazing stockpiled perennial forages to cows fed hay bales in drylot pens and found that the extensive feeding system had 19% lower total system cost.

2.3.2 Swath Grazing

Swathed annual crops can be left in the field for cattle to graze during fall and winter (McCartney et al., 2008; Baron et al., 2012; Kumar et al., 2012; Baron et al., 2014). Entz et al. (2002) found that grazing swathed forages provided an advantage over grazing stock piled forages due to increased grazing efficiency of cattle. Kumar et al. (2012) found that calves grazing whole plant swathed barley gained similar to calves fed in a drylot pen system (0.8 kg/d) and DMI was similar between treatments, 7.76 and 7.53 kg/hd, respectively. Another advantage to swath grazing for backgrounding is the ability for the producer to control the maturity of the forage (May et al., 2007; Baron et al., 2012). Spring seeded barley and oat are the most common crops used for swath grazing (May et al., 2007) while triticale has been shown to have the most flexible seeding dates (Baron et al., 2012). Khorasani et al. (1997) reported that CP content of

small grain cereals will decrease with plant maturity, but that CP content will plateau around 1 to 3 weeks before harvest at the soft dough stage (23% CP at boot stage and 15% CP at soft dough stage). Fiber concentrations follow a reverse pattern where content initially increases, plateaus, and then decreases during leaf growth (Khorasani et al., 1997). Aasen et al. (2004) also found that weathering, winter precipitation, and snowmelt decreased the nutritive value of swathed cereal annuals and peas.

While swath grazing can be the least expensive option for winter backgrounding programs, it is important to understand that some wastage of the forage will occur. Volesky et al. (2002) reported that forage waste for calves grazing windrowed cool season annual grasses was higher than calves fed round hay bales (29 and 12.5%, respectively). The authors also mentioned that placing mature cows on the same pasture following calf grazing can be a strategic plan to utilize the remaining feed. The amount of refused feed was reduced to 11% and thus provided an excellent way to decrease costs associated with maintaining a breeding cow herd (Volesky et al., 2002). Limit grazing is a technique that can also be used to minimize wastage by forcing cattle to clean up forage before they are allowed access to a fresh section of forage (Baron et al., 2014). Limit grazing also reduces wastage due to high hoof traffic or trampling (Hitz and Russel, 1998).

2.3.3 Bale Grazing

Swathed grasses and cereals can also be mechanically baled and left in the pasture for cattle to access through late fall and winter (Volesky et al., 2002; Nayigihugu et al., 2007; Kelln et al., 2011). In western Canada, this approach can make access to feed easier once snow depth becomes a problem during winter months and may also reduce feed wastage (Nayigihugu et al.,

2007). Nayigihugu et al. (2007) compared windrowed forage grazing to bale grazing in Wyoming and found that wastage was reduced by 57% in the management system of bale grazing. Nayigihugu et al. (2007) also mentioned that snow accumulation can create an icy crust on the windrows that limits feed access. A study by Kelln et al. (2011) evaluated four different winter feeding systems over a 3 yr period and determined that cows bale grazing in pasture paddocks were able to maintain and even increase weight when compared to cows fed a hay ration in drylot pens (10.4 and 28.2 kg during the winter grazing period, respectively). In addition, bale grazing system costs were 8% lower than pen feeding round bales due to decreased labor and yardage costs (Kelln et al., 2011). While it is a common practice for maintaining the beef cow herd, there is limited research on the use of bale grazing systems for growing calves. Research by Volesky et al. (2002) compared feeding calves on either a bale or a swath grazing system and found the cost of bale grazing was 37% higher than swath grazing. Bale grazing may have an increased total system cost compared to swath grazing, but the cost would be less than a drylot system and bale grazing also minimizes the risk of cattle not gaining access to swaths due to unfavorable weather conditions (Volesky et al., 2002; Nayigihugu et al., 2007; Kelln et al., 2011).

2.4 Determining Dry Matter Intake

The concept of determining DMI of an individual animal is important because intake is directly related to animal performance and productivity (Cook and Stubbendieck, 1986). Forages make up the largest portion of a grazing ruminant diet and plant material acts as the sole source of nutrients (Cook and Stubbendieck, 1986). Dry matter intake has always been believed to be directly related to the digestibility of the forage consumed, but there is also research

suggesting that the amount of forage available and gut fill may also influence intake (Jamieson and Hodgson, 1979; Jung and Allen, 1995; Allen, 1996). Jamieson and Hodgson (1979) determined that as herbage allowance decreased, bite size, rate of biting, and overall DMI was decreased in 4 to 9 mo old calves grazing perennial ryegrass. Allen (1996) explained that distension of the reticulorumen by high fill fibre diets will further reduce intake. High neutral detergent fibre (NDF) content in the forage will amplify this effect because it generally ferments and passes through the rumen slower than other feed constituents (Allen, 1996). Particle size and passage rate of feed can also affect intake as shown in early work by Welch (1967) which found that when 7 cm long polypropylene fibers were inserted in the rumen, DMI of alfalfa was reduced by 30% and gradually increased as those particles were broken down during rumination. When 30 cm long fibers were inserted, DMI was decreased by 75%, proving that particle size does in fact decrease intake (Welch, 1967). Many methods have been used in research to determine DMI of cattle, most of which were originally developed for housed animals (Cassady, 1941; Cook and Stubbendieck, 1983; Dove and Mayes, 1991; Hoffman et al., 1993; Cayley and Bird, 1996). It is much more difficult to accurately determine the intake of cattle fed in large drylot pens or grazing pasture (Cook and Stubbendieck, 1983; Dove and Mayes, 1991).

2.4.1 Monitor Systems

The direct method (s) of determining intake would be visual (or ocular) observation of grazing behaviors such as grazing time, bite size, and bite rate (Cook and Stubbendieck, 1983). The authors found that ocular estimates can be useful when applied to small areas, the errors in personal judgement tend to compensate each other, and the data can be statistically analyzed. While this can be useful in small controlled studies, it is not an ideal option for large extensive

grazing studies (Cook and Stubbendieck, 1983). Specialized equipment has been developed to record behaviour exhibited during grazing bouts. Greenwood et al. (2014) expanded on the use of GPS sensor tag systems and have developed a wireless sensor network (WSN) which is more adapted to large commercial grazing environments. The equipment records movements such as head lowering, biting, chewing, drinking, ruminating, walking, and lying down without having any affect on the natural behavior of the animal (Greenwood et al., 2014). These movements directly correspond to phenotypic measurements relating to productivity, efficiency, health, and welfare. However, the reliability and repeatability of these sensor systems is still questionable and further research should be considered (Greenwood et al., 2014).

2.4.2 Herbage Disappearance Technique

A direct measure technique for determining DMI of grazing cattle is the herbage disappearance technique which uses the difference between the weight of samples from randomly selected areas within the pasture pre and post graze (Cassady, 1941; Cook and Stubbendieck, 1983; Kelln, et al., 2011). The following equation represents the daily intake per animal (Cook and Stubbendieck, 1983):

$$\text{Equation 1.1 DMI (kg)} = (\text{DM available kg} - \text{DM residual kg}) / (n/p)$$

where, n is the number of animals and p is the number of grazing days. The sampling area should be of a pre-determined size to ensure consistency in the data. It is also important to have a relatively high number of samples to reduce error. When measuring stockpiled forages, a quadrat may be most suitable for both pre- and post-graze but there is potential for error due to

regrowth (Cook and Stubbendieck, 1986; Volesky et al., 2002; Kumar et al., 2012). Research using swathed forages often describes using a weight of 4 m of pre and post grazed swath length and applying the width of the harvester to the calculation (McCartney et al., 2004). Corn forage yield can be determined by measuring the length of pre-grazed rows, where the DM weight of a section of corn row directly corresponds to 0.0004 ha (1/1000 acre) (Mueller and Sisson, 2013). Post-grazing measures must be treated differently due to trampling of the crop; thus, it is recommended to use quadrat sampling similar to stockpiled forage sampling (Cook and Stubbendieck, 1986).

2.4.3 Pasture Cage Comparison Technique

This technique measures DMI of the entire group of animals in the paddock based on the difference of herbage mass in a grazed and ungrazed area. Animals are excluded from an area for a period of up to 4 weeks by the use of a wire mesh pasture cage approximately 2.5 m in diameter (Cook and Stubbendieck, 1983). The following equation can be used to also determine the net pasture growth rate (NPG) (Cayley and Bird, 1996) and percent utilization (Hoffmann, et al. 1993):

$$\text{Equation 1.2 NPG} = \{ \text{herbage mass (day t)} - \text{herbage mass (day 0)} \} / \text{day t}$$

where, day t is the number of grazing days.

$$\text{Equation 1.3 \% utilization} = ((\text{caged standing crop} - \text{ungrazed residue}) / \text{caged standing crop}) \times$$

100

2.4.4 Indigestible Markers

It is also possible to use fecal output and indigestible markers as a means to determine feed intake. The following equation can be used when the digestibility of the feed is known and total collection of feces is possible (Dove and Mayes, 1991):

$$\text{Equation 1.4 Intake} = (\text{Fecal Output}) / (1 - \text{Digestibility})$$

Total fecal collection is not an advantageous option for determining intake of grazing animals however; it is laborious and requires individually housed animals (Cook and Stubbendieck, 1983). Chromic oxide (Cr_2O_3) or Cr EDTA can be used as external fecal markers. The accuracy of using such markers highly depends on full recovery of the marker during analysis as partial recovery would overestimate fecal output (t'Mannetje and Jones, 2000). For the use of predicting intake in grazing animals, Furnival et al. (1990) suggested placing fistulated animals dosed with the marker into the test herd of grazing animals. The fistulated animals can therefore act as representatives for the rest of the herd.

Another option is the use of external markers such as Ytterbium (Yb) or long chain alkane (plant) waxes like C_{32} and C_{36} (t'Mannetje and Jones, 2000). It has been shown that by dosing the animal with 2 different markers greater accuracy can be achieved. To ensure a continuous, accurate release of the marker controlled-release devices can be used for up to 14 d or more (t'Mannetje and Jones, 2000). Intake is calculated using the following equation (Dove and Mayes, 1996):

$$\text{Equation 1.5 Intake} = (\text{Fi}/\text{Fj}) \times \text{Dj} / (\text{Hi} - (\text{Fi}/\text{Fj}) \times \text{Hj})$$

where, H_i and H_j represent concentrations of natural and dosed alkanes in herbage, F_i and F_j represent concentration in feces, and D_j is the dose rate.

2.5 Methods of Determining Forage Digestibility

Since forage DMI is directly related to forage digestibility, several methods to determine apparent and true digestibility have been developed (Tilley and Terry, 1963; Van Soest, 1991; Krizsan et al., 2013). Van Soest and Robertson (1985) provide definitions for both true and apparent digestibility where; i) true digestibility is the difference between the mass of original sample taken for incubation and the mass of the neutral detergent fiber fraction that remains after fermentation, and ii) apparent digestibility is the difference between the mass of the original sample taken for incubation and the mass of the dried residue that remains after fermentation. Three different methods are currently used in determination of digestibility, each with their own advantages and disadvantages.

2.5.1 *In Situ* and *In Vivo*

The *in situ* nylon bag technique has been used in research for many years and has been useful in describing rumen degradation kinetics. Feed samples are placed in nylon bags which are then directly placed in the rumen of a cannulated cow (Gosselink et al., 2004; Krizsan et al., 2013). Direct placement surpasses even the closest simulation to the rumen environment because temperature, pH, buffer, substrates and enzymes are all naturally occurring (Nocek, 1998). Even with this feature, there are still disadvantages associated with *in situ* work. Nocek (1988) has shown that pore size of the nylon bags, particle size of the feed, and sample size can all have an effect on the true ruminal digestibility of feeds. Furthermore, Krizsan et al (2013)

found in meta-analysis comparing *in situ* with *in vitro* techniques that *in situ* underestimated true NDF digestibility. This underestimation was greater for feeds with low digestibility, such as grass hay and silage.

Cell wall components such as ADF and lignin can also be used as indigestible markers and applied *in vivo* to determine digestibility (t'Mannetje and Jones, 2000). Acid detergent fibre (ADF) is more closely related to digestibility than NDF or lignin, therefore ADF has been used as a predictor, however lignin has proven to be more accurate with the use of equations where the unignified portions can be treated separately from lignified cell wall portions (t'Mannetje and Jones, 2000). Indigestible markers *in vivo* use the following equation (Cook and Stubbendieck, 1983):

$$\text{Equation 1.6 Digestibility} = 100 - \left[100 \times \frac{\% \text{ indicator in forage}}{\% \text{ indicator in feces}} \times \frac{\% \text{ nutrient in feces}}{\% \text{ nutrient in forage}} \right]$$

2.5.2 *In Vitro*

Researchers have used several different *in vitro* filter bag techniques to determine digestibility in the rumen, including the Tilley and Terry method for apparent digestibility (Tilley and Terry, 1963), the traditional technique for true digestibility (Van Soest et al., 1991), and a technique using Daisy^{II} incubator (ANKOM Technology Corporation, Fairport, NY). Several disadvantages have been shown in previous literature for each of these filter bag methods. These include, i) potential for some particulate matter to escape through the pores of the filter bag, altering residue weights (Ellis et al., 1994); ii) influence of samples on each other when incubated in the same vessel (Wilman and Adesogan, 2000); and iii) samples collected for

analysis may not accurately represent the grazing animal diet due to selection (Coates and Penning, 2000). However, keeping these disadvantages in mind, these techniques have also been shown to be successful in determining *in vitro* digestibility due to high accuracy and improved repeatability. Comparison studies between *in situ*, *in vivo*, and *in vitro* techniques have determined that *in vitro* can also reduce the labor and cost of determining digestibility (Holden, 1999; Krizsan et al., 2013).

2.6 Estimation of Animal Performance

For any enterprise to be successful there needs to be an achievable profit margin where input costs are recovered and surpassed. In animal production systems the overall performance of the animal will ultimately determine the profitability of the operation. The variables that depict performance could be body weight, body fat deposition, and carcass characteristics (Lowman et al., 1976; Berge, 1991; Coates and Penning, 2000). It is necessary to have a means of estimating performance of either the individual or the herd (Schroder and Staufenbiel, 2006).

2.6.1 Body Weight and Condition Scoring

The most common and practical method of determining performance of mature and growing animals is recording the individual body weight (Schroder and Staufenbiel, 2006). For a mature beef animal, such as a dry pregnant beef cow, it is ideal that they maintain BW without having major losses or gains (Schroder and Staufenbiel, 2006). For a growing animal, a targeted average daily gain (ADG) will be expected (NRC, 2000). In grazing research animals will be weighed frequently throughout the course of the trial as BW will provide insight on the quality of the feed provided (Kumar et al., 2012; Kelln et al., 2011; Bodine and Purvis, 2003). There is

potential for live weights to be misleading due to either gut fill or fetal growth (Wright and Russel, 1984). To avoid errors due to gut fill, time of day for weighing should be taken into consideration. Research suggests 2 consecutive weigh days occurring 3 to 4 h after sunrise, just before intensive grazing starts for that day, or fasting the night before (Coates and Penning, 2000). The use of a body condition scoring system (BCS) may be beneficial for assessing pregnant beef cows. A BCS simply estimates the amount of energy reserves/fat reserves an animal is carrying by visual and manual palpation of subcutaneous stores (Lowman et al., 1976). Lowman et al. (1976) suggests a 5 point scale for Canadian operations, where a score of 1 is an emaciated, nutrient deprived animal and 5 is a very fat, obese animal.

2.6.2 Body Fat Ultrasonography

The use of ultrasonography to measure body fat thickness is another means of determining performance. Where BCS is an acceptable means of assessing body fat reserves, it is a subjective approach based on an individual technician's decision and there will be differences from one person's score to the next (Schroder and Staufenbiel, 2006).

Ultrasonography minimizes this issue by producing a concrete image where exact measurements can be taken, thereby increasing accuracy and repeatability (Brethour, 1992; Hassen et al., 1998). Research has suggested that images of the 12th rib fat are more accurate in providing information about body composition and in predicting USDA Yield Grade (Greiner et al., 2003; Wall et al., 2004). The longissimus muscle area and marbling can also be accurately measured since the development of a longer ultrasound transducer (Herring et al., 1994).

Ultrasonography can be useful for predicting when a feedlot animal may reach finish weight, as there is the potential to reduce days on feed by sorting animals based on their body composition

(Wall et al., 2004). This process does require more time, labor, and an experienced technician and can create more stress on the animal so it may be most common for application in feedlots and research than in an extensive grazing program (Drake, 2004).

2.6.3 Finished Carcass Composition

The finished beef feedlot animal is graded based on the final carcass characteristics (Berge, 1991; Vaage et al., 1998; Mathis et al., 2008; Kumar et al., 2012). These grading systems include: i) Dressing percentage, where the carcass weight is represented as a percentage of the liveweight using the following equation (Primefacts, 2007):

$$\text{Equation 1.8 Dressing \%} = (\text{carcass weight/liveweight}) \times 100$$

ii) Yield grade, where lean yield of the overall carcass is measured by use of a specially designed ruler. The grade system uses a 3 point scale where a 1 is desirable lean yield and a 3 has reduced lean yield (Canada Beef, 2012); iii) Quality grade, where the “youthfulness” of a carcass is graded by a certified grader and referred to as either Canada A, AA, AAA, or prime. The grading system is based on maturity of the animal, meat color, fat color, carcass marbling, fat coverage and texture, and meat texture (Canada Beef, 2012); and iv) Marbling score, where the amount of intramuscular fat is graded on a 10 point system where 1 is abundant marbling, 5 is moderate, and 10 is devoid of marbling (Kumar et al., 2012).

2.6.4 Residual Feed Intake

Providing feed just to meet maintenance requirements of cattle is roughly 60 to 75% of total feeding costs (Archer et al., 1999; Basarab et al., 2003). In an effort to minimize costs associated with feeding, researchers have begun to look at the influence of genetics on feed

conversion (Archer et al., 1999). Residual feed intake (RFI) is defined as the difference between an animal's actual feed intake and its expected feed requirements for maintenance and growth (Koch et al., 1963). A positive value suggests that the animal is consuming more than predicted, whereas a negative value means the animal is eating less than predicted (Nkrumah et al., 2006). It can be concluded that an animal with a negative RFI value is economically more efficient and likely has an improved feed to gain (F:G) ratio (Koch et al., 1963; Nkrumah et al., 2006). Archer et al. (1999) explained that due to improved F:G ratio, it is possible to feed growing cattle less without affecting growing performance and final carcass composition. However, RFI was originally estimated from a phenotypic regression using correlations between RFI and production traits and it is not certain if these values would represent real measurable data (Archer et al., 1999). The development of the GrowSafe feed systems (GrowSafe Systems Ltd., Airdrie, Alberta) has since improved the ability of researchers to accurately and efficiently measure RFI. Basarab et al. (2003) evaluated 90 feedlot steers over a 120 d period and found a range in RFI values where the most efficient steers were documented at -1.95 kg/d (0.55 kg/hd/d DM) and the least efficient were at +1.82 kg/d (0.93 kg/hd/d DM), representing a feed difference of 3.77 kilograms. The authors also found that this difference in consumed feed represented reduced costs of \$0.38/d and \$45.60/head over a 120 d feeding period. By utilizing RFI genetic merit sires, producers can potentially lower total feed costs without creating any negative effects on the finishing performance of steers (Basarab et al., 2003; Nkrumah et al., 2006).

2.7 Effect of Background System on Feedlot Finishing

Backgrounded cattle typically experience a period of nutrient restriction which is meant to cause a slow rate of gain with little fat deposition, while still allowing skeletal frame growth

(Perrillat et al., 2003). The weight gain seen in growing cattle that have experienced a period of feed or nutrient restriction is often referred to as compensatory gain (Klopfenstein et al., 2000). Following backgrounding, cattle will show a period of increased daily gains, allowing them to catch up to their counterparts who have been placed on high energy finishing diets earlier (Klopfenstein et al., 2000; Mathis et al., 2008; Winterholler et al., 2008; Kumar et al., 2012). Research supports the idea that the maintenance CP and energy requirements for the animal is reduced by about 20% following the period of restriction, thus allowing it to gain faster (Van Soest, 1994). The duration for compensatory gain is believed to be roughly 60-90 d following restriction (Van Soest, 1994) and will compensate for 50-60% of the restriction (Klopfenstein et al., 2000). Work by Vaage et al. (1998) used feedlot steers which were either placed on a typical high grain finishing diet or on an extended backgrounding forage based diet. The authors found that the grain fed steers reached finishing sooner, but at a lighter weight, and overall carcass characteristics were not affected (Vaage et al., 1998). Vaage et al., (1998) concluded that restricting either the intake or energy content of diets fed to steers caused prolonged skeletal and muscle growth while delaying the deposition of fat. Winterholler et al. (2008) compared calves placed on a finishing diet following weaning to yearling steers placed on the same finishing diet after they were grazed on wheat pasture. The authors found that backgrounded yearlings with larger skeletal frames had higher DMI, ADG, HCW, and ribeye area after finishing with no effect on final carcass quality grade once harvested.

2.8 Summary of Literature Review

The option of using extensive winter grazing systems for beef calves has become a strategy that many producers have adopted into their operations due the potential to capture cost

savings while still maintaining animal performance and health. Cool season cereal and grass species have been the most common forage types used for extensive grazing, but there is also some application of warm season cereals. The recent introduction of low heat unit corn varieties to Western Canada has provided producers an alternative forage choice for winter grazing systems as the crop can provide adequate energy and protein for growing beef calves as well as high biomass yields. The effect of background extensive winter pasture grazing vs traditional pen feeding on finishing performance of beef calves is another important factor to take into consideration. Past research has found that backgrounding winter grazing systems had no effect on ADG, body weight or carcass characteristics during the finishing feedlot phase. Compensatory gain plays a major role in the final finishing performance of steers managed in an extensive winter grazing system. Extensively backgrounded animals may enter the feedlot at lower BW than animals backgrounded in a drylot pen system, but due to increased DMI and lower metabolic rate they will exhibit compensatory gain to drylot pen fed steers. This review of the literature has lead to the hypothesis that whole plant corn may be a suitable forage in extensive winter grazing systems due to the similar digestibility, nutritional profile and biomass compared to whole plant barley. It is also hypothesized that backgrounding beef calves managed on extensive winter grazing systems will have DMI, ADG, and final carcass characteristics similar to calves fed processed hay in a drylot bunk system.

3.0 In vitro digestibility of corn and barley varieties collected at two calendar dates during a winter backgrounding trial

3.1 Introduction

It has been shown in previous research that intake is largely affected by physical gut fill of the animal and NDF fermentation of forages within the rumen (Masoero et al., 2006). As forages mature, there is increased lignification of plant structures, which would increase the fibre content (ADF; NDF) and result in decreased dry matter intake and digestibility (Welch, 1967; Van Soest, 1994; Allen, 1996; Johnson, 1999). New corn varieties adapted to western Canadian growing conditions have been introduced. It is important to determine the apparent and/or true digestibility of these forages within the rumen. The characterization of corn needs to be compared to other common forages that are used for winter grazing, such as whole plant barley. A comparison of digestibility at different collection dates should be determined to account for any changes occurring due to maturity or weathering effects. The objective of this experiment was to compare *in vitro* digestibility characteristics of whole plant corn, whole plant barley, and barley hay collected by field sampling at 2 different calendar dates.

3.2 Materials and Methods

3.2.1 Sample Collection

Each yr, a portion of the barley crop was swathed in late August at the soft dough stage and left in windrows for winter grazing while the remaining crop was baled shortly after swathing at approximately 90% DM. The bales were stock piled on the ranch yard site and

processed into green feed hay. The corn crop was left standing for winter grazing with the first killing frost occurring in late October in each yr of the study.

Replicate (n=2) field samples of whole plant barley (*Hordeum vulgare*; c.v. Ranger), whole plant corn (*Zea mays*; c.v. Pioneer P7443R), and processed barley hay were collected at the start (yr 1: December 12; yr 2: October 16) and end (yr 1: February 13; yr 2: February 20) from a companion study, resulting in a total of 24 samples over 2 year. Grab samples from each replicate paddock of whole plant corn and whole plant barley forage were collected and mixed to make one composite sample per replicate. Composite samples from stockpiled processed barley hay forage were also collected in replicate. Forage samples were then dried at 55°C for 72 h in a forced air oven and were ground to pass through a 2-mm screen (AOAC 2000) using a Wiley mill (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific, Swedesboro, NJ) prior to determination of *in vitro* digestibility of DM (IVDMD) and NDF (IVNDFD).

3.2.2 Weather Data

Monthly temperature and wind speed were obtained from the Termuende Research Ranch Benchmark Site meteorological station located 2 km north east of the study site. Precipitation and snowfall data were obtained from the Environment Canada's Climate Data for Esk, Saskatchewan, approximately 5 km south east of the study site (51°48'N, 104°51'W; <http://www.comiate.weatheroffice.ec.gc.ca>). Accumulated corn heat units (CHU's) were obtained from Saskatchewan Crop Insurance Corporation weather station in Duval, located 80 km south of the study site.

3.2.3 *In Vitro* Incubation

In vitro digestibility of DM and NDF was determined using the Daisy^{II} incubator (ANKOM Technology Corporation, Fairport, NY) as described by Holden (1999) and Spanghero et al. (2003). ANKOM F57 filter bags were washed in acetone and dried prior to the addition of approximately 0.5 g sample/per bag. Four jars were required to run a quadruplicate *in vitro* system containing replicate (n=2) samples of whole plant barley, whole plant corn, and barley hay over 2 years. Each jar contained one replicate of forage samples, a blank filter bag and a standard sample, for a total of 26 samples. The samples were incubated for 48 h to measure total digestibility as this is the recommended incubation time for the Daisy^{II} technique (Johnson et al., 1962; Damiran et al., 2008; Wilman and Adesogan, 2000). Rumen contents were collected from 3 ruminally cannulated donor cows fed a 100% grass hay forage based diet. Approximately 4L of rumen content were collected and transported in a pre-warmed (39°C) thermos to the lab where the fluid was strained through 4 layers of cheesecloth into a 1L flask, then placed in a warm 39°C water bath. To ensure anaerobic activity of microorganisms, CO₂ was continuously flushed through the rumen fluid (Kriszan et al., 2013). A solution consisting of a buffer solution (1600 mL) and rumen fluid (400 mL) were added to each jar and purged with carbon dioxide. Following incubation, all bags were washed 3X with warm tap water to ensure a thorough rinse which reduced the residue weight by removing any microbial/small particle matter leftover and ultimately improving the digestibility estimate. All bags were then submerged in an NDF solution with the inclusion of alpha amylase and sodium sulfite using an ANKOM TM200 fiber analyzer (ANKOM Technology, Fairport, NY) according to the procedure of Damiran et al. (2008).

3.2.4 Calculations

In vitro dry matter digestibility was calculated using the following equation (Damiran et al., 2008);

$$\text{Equation 3.1 IVDMD} = (1 - ((W_3 - (W_1 \times C_1)) \times 1000) / (W_2 \times \text{DM}))$$

where, W_1 is the filter bag tare weight, W_2 is the forage sample weight (as is), W_3 is the final bag weight after *in vitro* incubation (filter bag + residue ash) and C_1 is the blank bag correction (comparison of weight before and after incubation), and DM is the dry matter content (g/kg) of samples.

Following *in vitro* digestibility, NDF was determined using the ANKOM fibre analyser (ANKOM Technology Corporation, Fairport, NY). Neutral detergent fibre degradability (NDFD) was calculated using the following equation (Damiran et al., 2008);

$$\text{Equation 3.2 NDFD} = (1 - (([W_3 - \{W_1 \times C_1\}] \times 1000) / (W_2 \times \text{NDF})))$$

where, W_1 is the filter bag weight, W_2 is the sample weight (as is), W_3 is the final weight (filter bag + residue ash) after *in vitro* incubation and sequential treatment with NDF solution, C_1 is the blank bag correction (comparison of weight before and after incubation), and NDF is the NDF content (g/kg) of samples.

3.2.5 Statistical Analysis

In vitro digestibility of DM and NDF was analyzed using the Proc Mixed model procedure of SAS Version 3 (SAS Institute Inc., Cary, NC). A randomized complete block design (RCBD) with repeated measures was used to analyze in vitro digestibility of NDF and dry matter. The experimental model was $Y_{ij} = \mu + \rho_i + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ij}$, where Y_{ij} was the dependent variable, μ was the overall mean, ρ_i was the random block effect of jar, α_i was the effect of the treatment (forage), β_j was the effect of the repeated measure (sampling date), $(\alpha\beta)_{ij}$ was the interaction effect between treatment and repeated measure and e_{ij} was the effect of repeated measure error. Type of forage crop acted as the treatment factor and the sampling period was the repeated measure, with a total of 24 experimental units over 2 yr. Jar was included as a random (block) variable in all analyses. Differences among the treatment means was also tested using Tukeys multiple range test and significance was recorded when $P < 0.05$.

3.3 Results and Discussion

There were no differences found ($P > 0.05$) for IVDMD or IVNDFD between COR and BAR forages and processed barley hay (Table 3.1). Maturity was terminated for both barley hay and whole plant barley when the forages were swathed at the soft dough stage and left in windrows to be sun-cured prior to baling. Past research has suggested that forages remaining out in the field may experience nutrient loss due to weathering effects, causing increased fibre concentration and decreased forage digestibility (Kilcher and Heinrichs, 1974; Johnson et al., 1999; Volesky et al., 2002; Aasen et al., 2004). The CON barley hay was baled shortly after it was cut and stored in the yard while BAR forage was left in windrows for grazing and COR forage was left standing. It was possible that the BAR and COR forage left in the field may have

encountered greater weathering effects than stored barley hay bales, thus resulting in increased nutrient leaching and leaf senescence. Rainfall was greater in yr 1 of the trial during August harvest (43.4 vs 9.2 mm) which further suggests that there may have been increased weathering and nutrient loss for barley swaths and standing corn compared to baled barley hay (Appendix A.1). However, there were no differences found ($P>0.05$) for IVDMD or IVNDFD between the early October and late February sampling dates for the 3 forages (Table 3.1).

Previous literature found that DM and NDF digestibility of whole plant corn and whole plant barley decreased with advancing maturity due to increasing fibre concentration (Masoero et al., 2006; Rosser et al. 2013). Masoero et al. (2006) compared the IVDMD and IVNDFD of the stalks and leaves of 3 different corn hybrids at different vegetative stages. On average, IVDMD and IVNDFD decreased from the dough stage to physiological maturity for both stalks (61.2 and 38.6% vs 52.4 and 34.8%, respectively) and leaves (72.8 and 53.8% vs 69.2 and 50.2%, respectively) (Masoero et al., 2006). Weaver et al. (1978) also found that IVDMD decreased during maturation in the husk, leaf and stalk of the corn plant. A study by Rosser et al. (2013) using the *in situ* technique reported values for DMD and NDFD of whole plant barley at various stages of maturity. Whole plant barley DMD decreased with advancing maturity from late milk to hard dough (44.7 and 40.3%) while NDFD increased with advancing maturity (58.3 and 71.6 %, respectively).

Table 3.1 In vitro digestibility (%) of three forages collected at 2 sampling dates over 2 yr

Item ³	Backgrounding forage ¹						SEM	<i>P</i> -value ²		
	CON		COR		BAR			F	D	F×D
	Oct	Feb	Oct	Feb	Oct	Feb				
IVDMD	67.0	67.7	68.5	65.3	66.8	65.4	1.42	0.82	0.14	0.19
IVNDFD	45.3	45.8	51.8	43.1	46.5	42.3	5.02	0.71	0.06	0.16

¹CON = barley hay; COR = whole plant corn; BAR = whole plant barley; Oct = Dec 12, 2012 and Oct 16, 2013 sampling date; Feb = Feb 13, 2013 and Feb 20, 2014 sampling date.

²F = forage; D = date; F×D = forage by date interaction.

³IVDMD = in vitro dry matter digestibility; IVNDFD = in vitro neutral detergent fiber digestibility.

Even though *in vitro* organic matter digestibility (OMD) and *in vitro* crude protein digestibility (CPD) were not evaluated in this study, other research has shown that OM and CP digestibility will also change as the plant matures (Rosser et al., 2013). Rosser et al. (2013) compared whole plant barley at the late milk and hard dough stages and found that OMD decreased (41.2 and 38.3%, respectively) while CPD increased (25.6 and 28.3%, respectively). Starch content of forages has also been found to increase as the plant matures due to the formation of grain kernels in the head of the plant (Volesky et al., 2002). Rosser et al. (2014) found that as whole plant barley matures from late milk to ripening, starch content increases from 3 to 24.6 percent. However, total tract starch digestibility was not different ($P>0.05$) due to maturity (90 and 91.5%, respectively), suggesting that starch digestion is not affected by maturity (Rosser et al. 2014). In addition, Beauchemin et al. (1994) found that cattle were able to breakdown whole grain corn more efficiently than barley or wheat grain by oral mastication. The author reported rumen DM digestibility (DMD) of masticated barley grain (41.9%) to be lower than corn grain (76.5%) (Beauchemin et al., 1994). When taking into consideration the kernel component of whole plant cereal forages the results from Beauchemin et al. (1994) might suggest that whole plant corn used in the current study would have higher IVDMD than whole plant barley. This was not evaluated in the current study but could be considered for future research.

3.4 Conclusion

With the introduction of low heat unit corn varieties, producers are growing and grazing whole plant corn in extensive backgrounding systems as an alternative to barley forage. It is

important to compare the digestibility of whole plant corn forage to whole plant barley forage when deciding which forage to graze in a field backgrounding system. *In vitro* dry matter and NDF digestibility was not different between whole plant corn forage, whole plant barley forage and barley hay. There also was no difference between October and February sampled forage. In conclusion, whole plant corn was found to be a comparable forage to whole plant barley for use in extensive grazing systems beef calves.

4.0 Evaluation of barley and corn varieties for extensive winter grazing systems for beef calves

4.1 Introduction

Drylot backgrounding systems in western Canada are common during the winter months and are fairly similar to traditional feedlot systems. The drylot backgrounding system is known to have numerous costs as it encompasses costs such as feed transportation, manure removal, grain/roughage purchase, labour and yardage (Anderson and Boyles, 2007; Kelln et al. 2011; Krause et al. 2013). In most cases, economic analysis found that the overall cost of winter feeding was decreased when a backgrounding system was utilized when compared to the traditional drylot system. Kumar et al. (2012) reported a 49% higher total cost of production and a 45% higher cost of gain (COG) for backgrounding calves in drylot pens compared to extensive field grazing whole plant barley. Alternative backgrounding systems and extensive winter grazing have become areas of interest because of the potential to lower costs associated with winter feeding management.

When considering a backgrounding program, the type of forage to be used must be carefully evaluated to ensure adequate forage quality. This would include factors such as forage nutrient composition, digestibility and yield. The requirements of the target animal should also be known, and for the purpose of this study the energy and protein requirements for a 250 kg weaned calf targeted to gain 0.8 kg/day are reported to be 9.8% crude protein (CP) and 60% total digestible nutrients (TDN) (NRC, 2000).

Cool season annual forages such as barley are well suited to western Canadian growing conditions and provide acceptable crop yield and quality as well as improved animal performance (McCartney et al., 2008). Grazing swathed whole plant barley in field paddocks has been studied previously in calf backgrounding systems in western Canada (Kumar et al., 2012). This research has shown that targeted beef calf performance can be achieved from winter grazing of barley swaths in field paddocks. Kumar et al. (2012) reported calves grazing whole plant barley gained 32% greater than millet swath-grazed calves and gained similar to drylot bunk-fed calves.

As an alternative to barley, corn is a warm season annual forage grown in western Canada predominately by producers for grain and silage production (Lardner, 2004). Interest in grazing whole plant corn has increased recently as new hybrid varieties have been developed and adapted for different areas of western Canada. Previous research has been conducted to determine cattle performance grazing swathed barley (McCartney et al., 2008; Kelln et al., 2011; Kumar et al., 2012), but there is limited information available on grazing whole plant corn in field paddocks. The nutritional content of whole plant corn is comparable to whole plant barley, which suggests that corn could potentially serve as an alternate forage for a beef calf winter grazing backgrounding program.

Therefore, the objective of this study was to compare two winter grazing systems utilizing swathed whole plant barley and standing whole plant corn to a traditional drylot bunk fed system. Additionally, using results from the forage digestibility study (Chapter 3), the field backgrounding study will determine if whole plant corn is an acceptable forage for winter grazing calves compared to whole plant barley or processed barley hay. A conclusion of both objectives will be based on forage quality and yield, animal performance and total system cost. Finally, the effect of backgrounding program on feedlot finishing performance of same animals will also be determined.

4.2 Materials and Methods

4.2.1 Site and Crop Management

A 2 yr beef calf backgrounding study was conducted at the Western Beef Development Centre's Termuende Research Ranch near Lanigan, Saskatchewan (51° 51 N, 105° 02 W). In spring of 2012 and 2013 (May 23, 2012; June 6, 2013), a 3.2 ha field was seeded to corn (*Zea mays*, 'Pioneer P7443R'; 10 kg/ha) along with 134 kg/ha of actual nitrogen (N) fertilizer. Also, in spring of 2012 and 2013 (June 7, 2012; June 6, 2013), a 4.0 ha field was seeded to barley (*Hordeum vulgare*, 'Ranger'; 109 kg/ha) along with 56 kg/ha of N fertilizer. Weed control in the corn crop was managed with 2 applications of 0.27 L/ha of glyphosate [N-(phosphoromethyl) glycine] (R/T 540; Monsanto Company Incorporated, Creve Coeur, MO, United States) each yr (June 1 and 5, 2012; June 26 and July 5, 2013). The barley crop received an application of 30 g/ha Refine M (DuPont Crop Protection, Valdosta, GA, United States), 0.16 L/ha Perimeter II (DuPont Crop Protection, Valdosta, GA, United States) and 400 mL/ac Axial BIA (Syngenta, Basel, Switzerland) tank mix each yr (June 8, 2012; June 26, 2013). Each yr, 2 ha of barley crop

was swathed at 5cm stubble height in late August at the soft dough stage and left in windrows for winter grazing. Another 2 ha of barley was swathed similarly, but the resulting forage was baled at approximately 90% DM, stock piled on the ranch yard site and fed as processed greenfeed in bunks in drylot pens. The entire 3.2 ha corn crop was left standing for winter grazing with the first killing frost occurring in late October in each yr of the study.

4.2.2 Backgrounding Systems and Grazing Management

Over 2 yr, backgrounding trials were conducted from 12 December, 2012 to 19 February, 2013 (yr 1, 68 d) and 17 October, 2013 to 21 February, 2014 (yr 2, 126 d). Each year, one hundred and twenty (120) fall weaned (yr 1: 174 d; yr 2: 164 d) Black Angus calves (yr 1: average body weight (BW) = 271 kg; yr 2: average BW = 255 kg) were stratified by BW and randomly allocated to 1 of 3 replicated (n=2) backgrounding systems: (i) grazing standing whole plant corn (COR) in field paddocks; (ii) grazing swathed whole plant barley (BAR) in field paddocks; or (iii) drylot pen feeding processed greenfeed hay (CON). All calves were implanted with 36 mg Zeranol (RALGRO®; Schering-Plough corp, Kenilworth, NJ, USA) and vaccinated with Tas-Vax 8 (a modified live *Clostridium chauvoei-haemolyticum-novyi* Type B, *Perfringens* Types B, C & D, *Septicum-tetani* Bacterin-Toxoid vaccine; Merck Animal Health, Madison, NJ, United States), Express 5 (a modified live BVD, IBR, PI3 vaccine; Boehringer Ingelheim, Burlington, ON, Canada), and Somnu-Star PH (a modified live *P.hemolytical*, *H.somni* vaccine; Novartis Animal Health, Mississauga, ON, Canada) at the start of the trial. The ration balancing program (CowBytes Version 5, Alberta Agriculture, Food and Rural Development, Alberta, Canada) was used to determine feed allocation based on BW, forage nutrient analysis, and environmental conditions. Field paddocks used for grazing were perimeter fenced with high tensile wire fencing and forage was allocated every 3 d by using portable electric fence to

maximize utilization and minimize wastage (Volesky et al., 2002; Kumar et al., 2012). Nutritive value of whole plant corn, swathed whole plant barley, and barley hay was determined prior to grazing to assess whether forage nutrient levels were adequate for targeted growth. All calves were supplemented with a 2:1 vitamin-mineral ratio range pellet [16% CP, 72% TDN; 13% ADF; 33 mg/kg monensin sodium (Rumensin 200; Elanco Animal Health, Guelph, ON, Canada)] daily, based on their weight to meet nutrient requirements during backgrounding and achieve a targeted ADG of 0.8 kg per day. Greenfeed was offered to BAR and COR calves for approximately 5 days at the start of the trial so that calves could gradually adapt to the extensive grazing system. Water was supplied daily in portable water troughs and 2 portable windbreaks (10 × 16 m) were provided for shelter to each replicate paddock group of calves. Drylot (CON) pen fed calves were housed in outdoor pens (50 × 120 m) and calves were bunkfed processed barley hay and pellet daily. Body weights of all calves were determined over 2 consecutive d at start and end of the trial and every 21 d during the trial to determine average daily gain.

4.2.3 Weather Data

Monthly temperature and wind speed were obtained from the Termuende Research Ranch Benchmark Site meteorological station located 2 km north east of the study site. Precipitation and snowfall data were obtained from the Environment Canada's Climate Data for Esk, Saskatchewan, approximately 5 km south east of the study site (51°48'N, 104°51'W; <http://www.comiate.weatheroffice.ec.gc.ca>). Accumulated corn heat units (CHU's) were obtained from Saskatchewan Crop Insurance Corporation weather station in Duval, located 80 km south of the study site.

4.2.4 Laboratory Analysis

Composite samples of whole plant barley, standing whole plant corn, and barley hay were collected before the start of trial and every 21 d throughout the grazing trial. Forage dry matter (DM) was determined by drying the samples at 55°C for 72 h in a forced air oven. After drying, samples were ground to pass through a 1-mm screen using a Wiley mill (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific, Swedesboro, NJ) and sent to Cumberland Valley Analytical Services, Maugansville, MD, United States for analysis. Duplicate samples were analyzed for total DM (AOAC; method 930.15), ash (AOAC; method 930.15), ether extract (EE) (AOAC, method 920.39), lignin (AOAC, method 973.18) (AOAC 1990) and acid detergent fibre (ADF) (AOAC; method 973.18) (AOAC, 1990). The Van Soest et al. (1991) procedure was used to analyze neutral detergent fibre (NDF) content of the forage samples. Both ADF and NDF were analyzed using an ANKOM™200 fiber analyzer (ANKOM Technology, Fairport, NY). Crude protein (CP) (N x 6.25) was determined using the Leco procedure (AOAC; method 990.03) (AOAC, 2000). The Kjeltec 2400 auto analyzer was used to determine acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble nitrogen (NDIN) (method 984.18; AOAC 2000) with residues recovered on Whatman No. 54 paper. Calcium (Ca) and Phosphorus (P) were analyzed after ashing for 5 h at 500°C using atomic absorption and UV visible spectrophotometer, respectively (AOAC, 2000). Total digestible nutrients (TDN) (% DM) were determined using the following equation based on apparent digestion (Weiss et al., 1992);

$$\text{Equation 4.1 } \text{TDN} = 0.98 * (100 - \text{NDFn} - \text{CP} - \text{ash} - \text{EE}) + e^{-0.012 * \text{ADIN}} * \text{CP} + 2.25 * (\text{EE} - 1) + 0.75 * (\text{NDFn} - \text{Lig}) * [1 - (\text{lig}/\text{NDF})^{.667}] - 7$$

where, neutral detergent fiber nitrogen-free (NDFn) = NDF- neutral detergent insoluble crude protein (NDICP) (NDICP = NDIN * 6.25), ADIN is expressed as a percent of total nitrogen (ADIN/N*100) and all other values are as a percent of dry matter.

4.2.5 Calculations

Randomly selected areas within each barley (n=15) and corn (n=5) paddock were sampled at the start of grazing to determine total forage (available) DM yield in each system. Dry matter was determined from 5 grab samples that were randomly collected in each replicate paddock and dried at 55°C for 72 h in a forced air oven. The barley crop was swathed prior to sampling and material from 25 randomly selected areas (3.0 × 3.7 m) were measured and weighed on a portable platform scale and replaced back in original location. The corn crop was left standing for grazing and all plants in 5 randomly selected areas (5.4 m) were harvested to a 5 cm stubble height and weighed on a portable platform scale. The whole plant corn material was further processed using a corn chopper to facilitate sampling and the resulting material was dried.

To determine post-grazed residue weight, 25 randomly selected residue samples (residual) from barley swaths (3.0 × 3.7 m) were measured and weighed using a portable platform scale.

Residue samples from corn (n=50) were collected using 1.0 m² quadrats and weighed using a portable scale. Dry matter intake (DMI) was estimated using the herbage disappearance technique per replicate group using the following equation (Jasmer and Holechek, 1984);

$$\text{Equation 4.2 DMI (kg)} = (\text{DM available (kg)} - \text{DM residual (kg)}) / (n/p)$$

where, n is number of animals and p is number of grazing days.

4.2.6 System Cost Analysis

For the field graze systems (COR; BAR), crop cost was determined for the consumed forage in all barley and corn paddocks. The cropping inputs (seed, fertilizer, and chemical), the number of passes required by equipment (harrow, seed, spray, and swath), and land rent were used to calculate the total crop production cost per hectare. The resulting value was then divided by the yield measurements to determine a price per kg of forage (% DM). Infrastructure costs included high tensile electric wire, portable electric fencing, windbreaks, and feed and water troughs. Yardage costs included equipment use, labor, and time to deliver the range pellet, mineral, salt, and water daily. Inputs for the CON system included current market value for greenfeed to determine price per kg of feed and supplements. Yardage costs were calculated using equipment cost, labor, time needed to deliver feed, and manure removal. Infrastructure costs included all fencing, windbreaks, shelters, watering bowls, and general repair on equipment. Equipment costs (tractor and the bale processor) were calculated using the custom rates published in 2013-2014 Saskatchewan Ministry of Agriculture Rental Rates Guide.

4.2.7 Feedlot Finishing Trial

Following the backgrounding phase all steers (n=120) were shipped 120 km to the University of Saskatchewan Beef Cattle Research Unit (BCRU) located at Saskatoon, Saskatchewan, Canada. In yr 1, the backgrounding trial ended sooner than expected due to heavy snowfall and calves (360 kg BW) were placed at the Termuende Research ranch in drylot pens and fed a backgrounding diet consisting of 77% forage and 23% grain for 60 days. Similar to this in yr 2, following the backgrounding phase, steers were fed in pens at the University feedlot and fed a similar backgrounding diet until they reached the same 360 kg body weight.

Upon arrival, all steers were vaccinated with Tas-Vax 8 (a modified live *Clostridium chauvoei-haemolyticum-novy* Type B, *Perfringens* Types B, C & D, *Septicum-tetani* Bacterin-Toxoid vaccine; Merck Animal Health, Madison, NJ, United States), Express 5 (a modified live BVD, IBR, PI3 vaccine; Boehringer Ingelheim, Burlington, ON, Canada), and Somnu-Star PH (a modified live *P.hemolytical*, *H.somni* vaccine; Novartis Animal Health, Mississauga, ON, Canada) following the feedlot processing protocol. The implant program for steers included administration of 36 mg Zeranol (RALGRO®; Schering-Plough corp, Kemilworth, NJ, USA) during processing and a second administration of 200 mg trenbolone acetate, 20 mg estradiol (Revalor 200; Merck Animal Health, Madison, NJ, USA) approximately 60 d later for finishing phase. Steers from the 3 backgrounding systems (CON, BAR, and COR) were sorted by backgrounding treatment and randomly assigned to 1 of 12 pens with 10 steers per pen. Steers were weighed over 2 consecutive days at the start and end of the trial, and every 14 d throughout.

Steers were initially provided 1 of 2 backgrounding diets designed to be isonitrogenous, consisting of 78% silage, 6% mineral pellet, and 16% grain supplied as either dry rolled barley grain or steam rolled corn grain for a targeted gain of 1.0 kg/head/d. Once the calves reached approximately 400 kg they were started on a step up program and provided 1 of 2 finishing diets designed to be isocaloric, consisting of 13% silage, 79.8% grain supplied as either dry rolled barley grain or steam rolled corn grain, 7% mineral pellet, and 0.2% limestone with a targeted final weight of 615 kg. Every 14 d grab samples (n=5) were collected from the backgrounding and finishing diets fed to steers during the feedlot trial. These samples were combined to make a composite sample, dried at 55°C for 72 h in a forced air oven and ground to pass through a 1-mm screen using a Wiley mill (Thomas-Wiley Laboratory Mill Model 4, Thomas Scientific, Swedesboro, NJ). Dried composite samples were then sent to Cumberland Valley Analytical

Services, Maugansville, MD, United States for analysis using the same previously discussed procedures (Section 4.2.4).

At the end of the trial once steers reached an average weight of 615 kg, all steers were transported to Cargill Meat Solutions, High River, AB, Canada for slaughter. At this site, carcass data was collected by Canadian Beef Grading Agency graders, including hot carcass weight, ribeye area, back fat, marbling score, quality and yield grade.

4.2.8 Statistical Analysis

Animal and system cost data from the backgrounding phase was analyzed using the Proc Mixed model procedure of SAS Version 3 (SAS Institute Inc., Cary, N.C. USA). A randomized complete block design (RCBD) was used to analyze crop yield, crop quality, DMI, BW, ADG, total system cost and COG over the 2 yr trial. The experimental model was $y_{ij} = \mu + \rho_i + \alpha_j + e_{ij}$, where y_{ij} was the dependent variable, μ was the overall mean, ρ_i was the block (or random effect), α_j was the treatment (or fixed effect), and e_{ij} was the error. The backgrounding treatments (COR, BAR, or CON) were considered fixed effects with 4 replicates per treatment and yr acted as the random block effect. Each replicate group of calves ($n=20$) was considered an experimental unit so over the 2 yr study there was a total of 12 experimental units ($n=4/\text{treatment}$). Differences among treatment means were also tested using Tukeys multiple range test and significance was recorded when $P<0.05$.

For the feedlot trial, steer data was statistically analyzed using the Proc Mixed model procedure of SAS Version 3 (SAS Institute Inc., Cary, N.C. USA). A RCBD split plot was used to analyze DMI, BW, ADG, dressing percentage, ribeye area, and marbling score. Quality and yield grade data were analyzed using the GLIMMIX macro (SAS Institute Inc., Cary, N.C. USA)

with a binomial error structure and logit data transformation. The experimental model was $Y_{ij} = \mu + \rho_i + \alpha_i + w_i + \beta_j + (\alpha\beta)_{ij} + e_{ij}$, where Y_{ij} was the dependent variable, μ was the overall mean, ρ_i was the block (or random effect), α_i was the effect of the whole plot main factor (backgrounding system), w_i was the whole plot error, β_j was the effect of the sub plot factor (finishing treatment), $(\alpha\beta)_{ij}$ was the interaction effect between the whole plot and sub plot, and e_{ij} was the effect of the split plot error. Each initial replicate group of steers ($n=20$) was split into two groups where one group ($n=10$) received dry rolled barley grain and the other group ($n=10$) received dry rolled corn grain. Backgrounding system acted as the main whole plot treatment factor, the replicates ($n=10$) were the sub plot factors and year was the random block effect. Each pen of steers was considered the experimental unit with an $n=6$ for each finishing grain diet over 2 yr. Differences among the treatment means were also tested using Tukeys multiple range test and significance was recorded when $P<0.05$.

4.3 Results and Discussion

4.3.1 Forage Yield and Quality

Dry matter yield of COR forage was greater ($P<0.01$) than BAR forage (12,369 kg/ha vs 10,464 kg/ha) (Table 4.1) which is supported by other studies which have also shown corn DMY to be greater than barley DMY (Lardner, 2004; May et al., 2007; Baron et al., 2014). A 3 yr study by Aasen et al. (2004) found barley yield (7,696 kg/ha) to be 38% lower than the average barley yield (10,465 kg/ha) in the current study. May et al. (2007) compared yields from various Saskatchewan locations over 3 yr and found the average yield for barley was 6,800 kg/ha and corn was 6,271 kg/ha, which is 35 and 49% lower than the barley and corn DMY determined in both yr of the current study. May et al. (2007), however, reported lower average precipitation

than the current study for both June (79%) and July (24%), which are the most productive months for vegetative plant growth. These results may suggest why DMY were greater for both COR and BAR forage in the current study.

Table 4.1 Forage DM yield and chemical composition of forages in backgrounding systems over 2 yr, (DM basis)

Item ²	Backgrounding System ¹			SEM	<i>P</i> -value
	CON	COR	BAR		
Yield (kg/ha, DM)	-	12369	10464	797.1	0.06
DM (%)	75.5a	58.0c	65.4b	3.13	<0.01
CP (%)	11.1a	7.9c	10.1b	1.33	<0.01
NDF (%)	60.3b	62.9ab	63.3a	4.80	0.03
ADF (%)	37.6	38.3	39.2	1.33	0.10
TDN ³ (%)	57.8b	62.3a	59.0b	1.07	<0.01
NEg ⁴ (Mcal/kg)	0.30b	0.36a	0.32b	0.015	<0.01
Ash (%)	7.8b	4.8c	8.4a	0.69	<0.01
Ca (%)	0.39a	0.20b	0.37a	0.041	<0.01
P (%)	0.27a	0.20c	0.23b	0.029	<0.01

¹CON = drylot pen fed processed barley hay; COR = grazing whole plant corn in field paddocks; BAR = grazing swathed whole plant barley in field paddocks.

²DM=dry matter; CP=crude protein; ADF=acid detergent fibre; NDF=neutral detergent fibre; TDN=total digestible nutrients; NEg=net energy for gain; Ca=calcium; P=phosphorus.

³TDN calculated from Weiss et al. (1992).

⁴Net energy for gain (NE_g) was calculated from animal performance by using prediction equation based on performance using Zinn et al. (2002) equation.

^{a,b}Means within a row with different superscripts differ ($P < 0.05$).

Dry matter yield can also be different from one year to the next due to the change in weather and growing conditions (Aasen et al., 2004; May et al., 2007; Baron et al., 2014). Precipitation from June to September was greater in yr 2 compared to yr 1 and the recorded 30-yr average (67.7 vs 48.2 and 54.0 mm, respectively). There was also greater accumulation of corn heat units observed in yr 2 (2013) compared to yr 1 (2012) (2678 and 2580 CHU, respectively) (Appendix A.2). This would suggest that a difference in DMY from yr 1 to yr 2 of the study could have been expected. The 10 yr recorded average heat units is 2227 CHU which is lower than the 2 yr average for the current study (2629 CHU) indicating a warmer than average growing season, which may further explain why DMY of barley and corn was greater than those recorded in past research (May et al., 2007).

Crude protein, P and Ca content of barley forage in CON and BAR systems was greater ($P<0.01$) than COR forage, while forage energy content and NEg was greater ($P<0.01$) in the COR treatment than the CON and BAR treatments (Table 4.1). This is similar to results reported in work by Lardner (2004) where corn had lower CP and higher TDN values compared to barley forage. McCaughey et al. (2002) managed standing corn and swathed barley forages for winter grazing and suggested that corn TDN actually increased during the grazing period. This is likely because corn remained standing and continued to mature up until the first killing frost, thus allowing increased TDN. The barley was swathed at the soft dough stage and maturity of the plant was terminated. Rosser et al. (2016) found digestible energy intake for heifers fed whole plant barley at 3 different maturity stages (late milk, hard dough, and ripe) to be 15.1, 16.0 and 16.8 Mcal/d, respectively, indicating that barley forage TDN will increase similar to that of corn forage with advancing maturity.

Corn DM was lower ($P<0.01$) than both CON and BAR forages (58.0 vs 75.5 and 65.4%, respectively) (Table 4.1). Dry matter content will increase with advancing maturity of the forage (Kilcher, 1981). Considering that barley forage was intended to be swathed at the soft dough stage, the DM content was similar to what has been reported in past literature. Kumar et al (2012) also utilized whole plant barley forage swathed at the soft dough stage and reported 75.2% DM for swathed barley and 83.8% DM for barley hay. Corn forage, however, was left standing so maturity and DM was dependent on the timing of the first killing frost so it is difficult to compare results found in the current study to past literature. The study period was (27 d) longer in yr 2 compared to yr 1 and forages may have also been exposed to increased nutrient loss due to weathering and senescence of mature plant parts (Kilcher, 1981). Starch content was not recorded in the current study but other research has suggested that, similarly to CP, it will also start to decline once past physiological maturity (Volesky et al., 2002; Aasen et al., 2004; Scaglia et al., 2014). This theory is supported by Scaglia et al. (2014) where the author found that as stock piled forage matured, non-fiber carbohydrates and water soluble carbohydrates declined 68 and 48%, and CP also declined from 15.7 to 11.8%, respectively.

The current study and previous research have suggested that weathering effects can reduce plant protein content, energy and starch content due to leaching and leaf senescence which results in concentrated fibre content (Volesky et al., 2002; Aasen et al., 2004; Scaglia et al., 2014). Also, the timing of swathing or the first killing frost can differ between years, further creating variation in plant fibre content. These reports further support results from experiment 1 which suggested that advancing maturity of forages may have a significant negative effect on *in vitro* NDF and DM digestibility and overall nutrient availability of maturing whole plant corn and whole plant barley forages for grazing beef calves.

4.3.2 Backgrounding Calf Performance

Over the 2 yr trial, forage and total diet DMI was not different ($P>0.05$) for calves managed in the CON, COR, or BAR backgrounding systems (Table 4.2). Calf DMI from the total diet was targeted to 2.5% BW and CON calves were consuming 2.5% while both BAR and COR calves consumed 2.2% of BW during the trial. There also was no difference ($P>0.05$) in ADG and FBW between the 3 backgrounding treatments (Table 4.2). Numerically, CON calves had a higher ADG (0.72 vs 0.58 kg/d, respectively) and FBW (329 vs 319 kg, respectively) compared to BAR and COR calves. This is likely due to the fact that CON calves consumed more feed and were able to achieve a higher gain. It is also worth noting that the amount of supplemented range pellet was adjusted every 21 d according to the increasing weight of the growing calves and that supplement DMI was reported as an average amount fed during the backgrounding trial.

Table 4.2 Effect of backgrounding system on dry matter intake (DMI) and beef calf performance over 2 yr

Item ²	Backgrounding System ¹			SEM	<i>P</i> -value
	CON	COR	BAR		
DMI, kg/d					
Supplement ³	2.1	2.1	2.1	-	-
Forage	5.2	4.3	4.2	0.46	0.26
% of BW	1.8	1.5	1.5	0.15	0.32
Total diet	7.4	6.4	6.2	0.48	0.25
% of BW	2.5	2.2	2.2	0.15	0.34
Initial BW, kg/d	263.5	263.4	263.2	8.28	0.24
Final BW, kg/d	328.9	319.0	318.7	4.68	0.09
BW change, kg/d	65.4	55.6	55.5	12.47	0.09
ADG, kg/d	0.72	0.58	0.58	0.069	0.09

¹CON = drylot pen fed processed barley hay; COR = grazing whole plant corn in field paddocks; BAR = grazing swathed whole plant barley in field paddocks.

²DMI = dry matter intake; BW = body weight; ADG = average daily gain.

³Supplement range pellet composition = 16% CP, 72% TDN, 13% ADF, 26% NDF, 0.49% NEg, 0.82% Ca, 0.49% P.

^{a,b}Means within a row with different superscripts differ ($P < 0.05$).

Extreme changes in winter weather regarding sub-zero temperatures, wind chill and snowfall have been reported in past studies to have an adverse effect on the performance of winter backgrounded calves in extensive grazing systems (Adams et al., 1986; Kloppfenstein et al., 1989; Krause et al., 2010; Kelln et al., 2011). The average temperature for yr 1 and yr 2 of the current study from October to March was -11.2°C and -13.0°C, respectively, which is lower than the recorded 30-yr average of -7.8°C (Appendix A.1). Kumar et al. (2012) reported warmer 3 yr average temperatures than the current study at the same site location, from October to January (-10.2°C). Snowfall was high early in yr 1 of the backgrounding trial (15 cm) compared to yr 2 (5 cm) which had an impact on the period length of the backgrounding trial. In yr 1 swath grazed calves were unable to access some areas of swathed feed and subsequently moved through available feed much quicker and the grazing period was shortened (Appendix Table 1). Kumar et al. (2012) reported that the 3-yr snow fall average from October to January was lower (2.0 cm) than the average of the current study at the same study location, which would further support the hypothesis that weather conditions could have had a negative effect on ADG and final BW of calves managed in the extensive winter grazing systems in the current study.

The average recorded wind speeds during the study period were higher in yr 2 than yr 1 (5.95 and 3.72 m/s, respectively) (Appendix A.1). The CON calves were housed in drylot pens with an open faced shed and fencing on 3 sides, which provided more protection from the wind than calves managed in COR and BAR field paddocks. The extensively grazed calves were provided 2 portable wooden slat fences for shelter, but if they choose to seek shelter from the wind, grazing time would be decreased and forage intake could be affected. Krysl and Hess (1993) stated in their review that environment factors and forage dry matter yield (DMY) can

alter grazing behavior. Adams et al. (1986) reported a similar conclusion where cows grazing native range had decreased grazing time and DMI during cold periods during the winter.

4.3.3 Backgrounding Cost Analysis

System cost analyses over the 2 yr trial are presented in Table 4.3. Crop production cost for the COR system was 71% higher ($P=0.05$) (116.50 \$/ha) compared to BAR system (68.00 \$/ha). The inputs for growing the corn crop were higher compared to the barley due to seeding costs (33.39 vs 9.31 \$/ha) and increased corn fertilization rate. Since corn was planted at the same site in both yr, field preparation costs associated with breaking up residue, harrowing, and cultivating were also increased compared to the barley system. However, even with the higher production cost, corn had 73% lower ($P<0.01$) yardage cost than the drylot barley hay system (0.39 and 1.49 \$/calf/d, respectively) and 46% lower ($P<0.01$) total system cost (1.40 and 2.57 \$/calf/d, respectively) (Table 4.4). The whole plant corn system also had numerically higher biomass yield (12,369 kg/ha) available for grazing which resulted in a lower forage cost per animal. Net return was also greatest for corn and barley grazing calves (65.03 and 61.60 \$/hd, respectively) compared to drylot pen fed calves (\$-28.85/hd) (Table 4.4). These results are supported by Kumar et al. (2012), where millet had higher production costs but low yields, thus resulting in a higher forage cost. The findings of McCartney et al. (2004) also support the current study results where total system costs for cows grazing swathed whole plant barley was lower than cows pen fed *ad libitum* straw and barley silage (0.84 and 1.54 \$/cow/d, respectively). The calculated cost of gain (COG) between the 3 backgrounding systems in the current study was not different ($P=0.60$), but COR was numerically lowest (\$2.40/kg) while BAR was highest (\$2.70/kg). These results are similar to other studies using extensive grazing systems for

backgrounding beef calves (Karantininis et al., 1987). Kumar et al. (2012) reported COG for calves grazing swathed barley was 31% lower than feeding calves in a drylot system. Mathis et al. (2007) reported that pasture backgrounded calves had a \$45 increase in net income when compared to calves backgrounded in drylot pens.

Table 4.3 Cost analysis of backgrounding systems over 2 yr

Item	Backgrounding System ¹			SEM	<i>P</i> -value
	CON	COR	BAR		
Crop yield, kg/ha	--	12369	10464	797.1	0.06
Crop production cost, \$/ha	210.49b	294.57a	183.32c	11.194	<0.01
Feed cost, \$/calf/d	1.03	0.97	1.07	0.142	0.16
Yardage cost, \$/calf/d	1.49a	0.39b	0.36b	0.242	<0.01
Bedding cost, \$/calf/d	0.05	0.04	0.05	0.008	0.73
Total system cost, \$/calf/d	2.57a	1.40b	1.48b	0.139	0.01
Cost of gain, \$/kg of gain	3.81	2.21	2.70	0.517	0.07

¹CON = drylot pen fed processed barley hay; COR = grazing whole plant corn in field paddocks; BAR = grazing swathed whole plant barley in field paddocks.

^{a,b}Means within a row with different superscripts differ ($P < 0.05$).

Table 4.44 Revenue analysis of backgrounding systems over 2 yr			
Item	Backgrounding System ¹		
	CON	COR	BAR
Start of Trial			
Weight, kg	263.5	263.4	263.2
Market Value, \$/cwt	168.04	168.14	168.10
Starting Value, \$/hd	442.78	442.88	442.44
Backgrounding Cost			
Days on feed	97	97	97
Cost/Head/Day, \$	2.57	1.40	1.48
Total Cost to Feed, \$	249.29	135.80	143.56
End of Trial			
ADG, kg/hd/d	0.72	0.58	0.58
Weight, kg	328.9	319.0	318.7
Market Value, \$/cwt	201.65	201.79	203.20
Ending Value, \$/hd	663.22	643.71	647.60
Net Return, \$/hd	-28.85	65.03	61.60

¹CON = drylot pen fed processed barley hay; COR = grazing whole plant corn in field paddocks; BAR = grazing swathed whole plant barley in field paddocks.

4.3.4 Steer Performance Feedlot Finishing

Following the backgrounding phase, steers were transitioned to the feedlot finishing phase. Chemical composition of backgrounding and finishing diets used during feedlot finishing is presented in Table 4.5.

Table 4.5 Ingredient list and chemical composition of feedlot total mixed ration over 2 yr

Item ²	Diet ¹			
	Backgrounding		Finishing	
	COR	BAR	COR	BAR
Ingredient List				
Grain (%)	16	16	79.8	79.8
Silage (%)	78	78	13	13
Mineral Pellet (%)	6	6	7	7
Limestone (%)	-	-	0.2	0.2
Chemical Analysis				
DM (%)	93.1	84.8	93.9	93.4
CP (%)	10.8	10.0	11.6	12.7
ADF (%)	32.0	30.0	11.2	11.6
NDF (%)	48.2	44.8	22.8	24.7
TDN ³ (%)	58.8	54.2	74.1	74.4
NEg (Mcal/kg)	0.32	0.29	0.52	0.52
Ash (%)	10.0	8.1	7.3	7.2
Ca (%)	0.75	0.63	0.81	0.81
P (%)	0.30	0.26	0.40	0.42

¹Backgrounding or finishing diet consisting of silage, mineral/vitamin pellet, with either COR = corn grain; or BAR = barley grain

²DM=dry matter; CP=crude protein; ADF=acid detergent fibre; NDF=neutral detergent fibre; EE=ether extract; TDN=total digestible nutrients; NEG=net energy for gain; Ca=calcium; P=phosphorus

³TDN calculated from Weiss et al. (1992).

Over the 2 yr study, steer DMI, ADG, REA, BF and marbling score were not different ($P>0.05$) between calves managed in the 3 backgrounding systems (Table 4.6). No differences ($P>0.05$) were found in steer carcass quality or carcass grade (Table 4.7). These results strongly support the hypothesis that calves can be backgrounded on extensive winter grazing systems without having any negative effect on feedlot finishing performance. These results also agree

with previous research where extensive grazing systems had no effect on final steer performance (Vaage et al., 1998; Mathis et al., 2008; Kumar et al., 2012).

However, less than 10% of the steers received a yield grade 1, which suggests a high body fat to lean meat yield. Drake (2008) states that fat thickness is the most influential factor when determining yield grade, as fat thickness increases, the yield grade number will also increase, thus indicating a carcass with reduced “cutability” and fewer closely rimmed retail cuts of meat. Since there is a direct relationship between days on feed and ADG, this could be avoided by reducing the total number of days on feed during the finishing period (Drake, 2008).

Since the COR and BAR backgrounded steers were able to gain similar to DL steers during feedlot finishing even though they finished the backgrounding phase at a lighter weight, suggests evidence of compensatory gain. This refers to the weight gain seen in growing cattle that have experienced a period of feed or nutrient restriction earlier in life (Klopfenstein et al., 2000). Compensatory gain was also observed in work by Kumar et al. (2011) where backgrounded steers grazing swathed whole plant millet and swathed whole plant barley gained more than steers backgrounded in drylot pens once they reached finishing at the feedlot (10 and 8 kg/d, respectively). Dry matter intake of steers was not different ($P>0.05$) between finishing treatments, but a trend ($P=0.08$) was observed where backgrounding treatment increased intake of COR and BAR steers (10.1 and 10.1 kg/hd/d, respectively) compared to CON steer DMI (8.8 kg/hd/d) during feedlot finishing phase. These results are supported by NRC (2000) which suggests that a major component causing compensatory gain is increased feed intake, which in turn causes greater efficiency for energy use.

Table 4.6 Effect of backgrounding system and grain type in finishing diet on steer feedlot performance over 2 yr

Item	Backgrounding System ¹						SEM	<i>P</i> -value ³		
	CON		COR		BAR			B	F	B×F
	CG	BG	CG	BG	CG	BG				
Body weight, kg										
Start	365.2	365.2	365.4	364.0	364.6	364.6	34.6	0.98	0.87	0.97
Final	664.1	666.3	674.7	666.2	666.4	669.0	19.6	0.49	0.73	0.37
DMI, kg/hd/d	8.7	9.0	10.1	10.1	10.1	10.0	1.00	0.08	0.80	0.90
ADG, kg/hd/d	2.1	2.2	2.2	2.2	2.2	2.2	0.11	0.32	0.70	0.74
NEm ⁴ , Mcal/kg	2.6	2.5	2.4	2.5	2.6	2.5	0.09	0.77	0.26	0.32
NEg ⁴ , Mcal/kg	1.9	1.8	1.7	1.8	1.9	1.8	0.08	0.76	0.25	0.34
HCW, kg	391.2ab	388.0ab	397.5a	384.0b	390.5ab	384.8ab	18.7	0.56	<0.01	0.20
Dressing %	58.9a	58.2ab	58.9a	57.6ab	58.5ab	57.4b	1.13	0.16	<0.01	0.53
REA, cm ²	44.0	45.3	47.1	46.2	46.0	46.3	33.0	0.55	0.67	0.43
BF, mm	12.6	12.6	13.1	12.6	12.6	12.7	0.28	0.69	0.55	0.46
Marbling ⁵	3.6	3.8	3.7	3.5	3.8	3.8	0.37	0.53	0.80	0.37

¹CON = drylot pen fed processed barley hay; COR = grazing whole plant corn in field paddocks; BAR = grazing swathed whole plant barley in field paddocks; CG = finishing ration with corn grain; BG = finishing ration with barley grain.

²DMI = dry matter intake; ADG = average daily gain; HCW = hot carcass weight; REA = rib eye area; BF = back fat; Marbling = marbling score

³B = backgrounding phase; F = feedlot phase; B×F = backgrounding*feedlot interaction effect

⁴Net energy for maintenance (NE_m) and gain (NE_g) was calculated from animal performance by using prediction equation based on performance using Zinn and Shen (1998) and Zinn et al. (2002) equation.

⁵Marbling score on a scale of 0 (no marbling) to 10 (abundant marbling).

Table 4.7 Effect of backgrounding system and finishing diet on carcass grading

Item	Backgrounding System ¹						<i>P</i> -value ²			
	CON		COR		BAR					
	COR	BAR	COR	BAR	COR	BAR	SEM	B	F	B×F
Quality Grade, %										
AA	17.9	10.5	7.5	10.8	16.7	11.1	5.4	1.00	1.00	1.00
AAA	79.5	89.5	90.0	89.2	75.0	88.9	5.7	0.61	0.18	0.54
Prime	2.6	-	2.5	-	5.6	-	2.1	1.00	0.98	1.00
Yield Grade, %										
Yield 1	5.3	-	10.0	-	5.0	-	4.0	0.43	0.10	0.43
Yield 2	36.8	25.0	40.0	21.1	55.0	21.1	10.3	0.98	0.96	0.64
Yield 3	57.9	75.0	50.0	78.9	40.0	78.9	10.3	0.78	0.20	0.52

¹CON = drylot pen fed processed barley hay; COR = grazing whole plant corn in field paddocks; BAR = grazing swathed whole plant barley in field paddocks.

²B = backgrounding phase; F = feedlot phase; B×F = backgrounding*feedlot interaction effect.

Beauchemin and McGinn (2005) compared feedlot diets containing corn or barley, and found starch content to be greater in corn than barley grain (66.7 and 54.5%, respectively). Once the grain was included in the total mixed ration containing silage, grain and a byproduct meal, the starch content of the diet containing corn grain was greater than the barley grain diet (58.3 and 46.8%, respectively) (Beauchemin and McGinn, 2005). Additionally, NRC (2000) shows that the NEg value for flaked corn grain is greater than barley grain (1.62 and 1.22 Mcal/kg, respectively). It is also worth noting that the barley grain used in the current study was dry rolled while the corn grain was steam rolled, possibly increasing total tract digestibility and average daily gain. A review by Huntington (1997) found that processing of whole grains will improve starch intake. The author reported starch intake for dry rolled corn and barley grain was 2.06 and 4.09 kg/d, respectively, while starch intake for steam rolled corn and barley grain was 6.91 and 4.53 kg/d, respectively (Huntington, 1997). It has since been concluded that the combination of gelatinization of starch granules via steam and the roll pressure disrupt the starch-protein matrix and create smaller grain fractions to increase the extent of starch digestion (Zinn, 1990; Zinn et al., 2002). Zinn et al. (2002) reported that NEg increased 16 to 26% for steam flaked corn compared to whole corn grain, and increased ruminal and total tract starch digestion compared to dry rolled corn (25 and 9%, respectively).

In the current study a difference in HCW was found ($P=0.01$) between steers finished on a corn grain based diet compared to those finished on a barley grain based diet. The COR backgrounded steers fed the corn grain finishing diet had greater ($P<0.01$) HCW than COR backgrounded steers fed the barley grain finishing diet (397.5 and 384.0 kg, respectively). Additionally, dressing percentage was greater ($P<0.01$) for COR and CON backgrounded steers fed the corn grain finishing diet. These results suggest that corn grain may be digested and

nutrients metabolized differently than barley grain, and may provide greater nutrient value for final carcass growth and marbling. Owens and Gardner (2000) reported that cattle fed flaked grains had heavier carcass weights than those fed dry rolled grains, which may be related to less escape of dietary starch from the rumen. Additionally, Zinn et al. (2002) also suggested that the NE values reported by the National Research Council (NRC) for flaked corn may have been underestimated, perhaps due to failure to consider the increased digestibility of the non-starch organic matter associated with flaking. This would in turn suggest that the diet in the current study may not be iso caloric since it was based on the current NRC recommendations.

4.4 Conclusion

Extensive winter grazing programs have been shown to work very well for beef cows, but there is little evidence to show success for backgrounding beef calves and the effect on final feedlot finishing performance. In addition, the use of whole plant corn forage is a new strategy for winter grazing in western Canada. In the current study, DMI, IBW, FBW and ADG was not different between calves' field grazing standing whole plant corn, field grazing whole plant barley or pen fed processed barley hay. Total system cost for calves grazing whole plant corn and barley was lower than calves fed barley hay in drylot pens. These results strongly support the hypothesis that field grazing either whole plant corn or barley is a good alternative to barley hay fed in a drylot pen. Following backgrounding, steers were placed in a feedlot finishing program. No difference was found in ADG and carcass characteristics between steers, further supporting the hypothesis that backgrounding calves can be placed on extensive winter grazing programs prior to feedlot finishing without causing any negative effects on finishing performance.

5.0 General Discussion and Conclusion

With today's high cost of feed the option to background weaned beef calves on extensive winter grazing systems utilizing either warm or cool season annuals is a viable alternative. A backgrounding program should be designed to allow skeletal growth without excess fat deposition, which would in turn reduce the amount of time that cattle would spend in a feedlot finishing program. The introduction of low heat unit corn varieties to Western Canada has increased the demand for new forage options for extensive winter grazing systems for beef calves.

The P7443R corn variety chosen for the current backgrounding study was found to have similar *in vitro* DM and NDF digestibility to barley forage suggesting that cattle could utilize the nutrients from whole plant corn similarly to whole plant barley. Corn was also found to have acceptable nutrient content and biomass yield compared to a traditional barley forage variety. Whole plant corn forage had high energy but low protein content compared to whole plant barley forage, which indicated the need for a supplemented range pellet to balance the nutritional needs of a growing calf. Total system costs for calves extensively grazing either swathed whole plant barley or standing whole plant corn was 42 and 46% lower, respectively, than calves drylot fed processed barley hay. Although it was not significant, COG for calves grazing COR forage was the lowest of the 3 treatments, most likely due to the high biomass yield of the corn crop. These results can, however, be variable year to year due to numerous factors.

The agronomic management of forage crops played a very large role in crop yield and quality. Since corn was relatively new to western Canada, differences between the management of the corn crop compared to a barley crop should be discussed. Corn seeding rate and seed placement could have a major role in crop establishment. The current recommendation is to

target a seeding rate of 28 - 42,000 seeds/acre at a seed depth of 1.5 - 2 inches and a minimum 15' row spacing (Mueller and Sisson, 2013). Corn in the post emergent vegetative stage isn't very competitive with weed species so proper application and timing of herbicide was also very important (Gower et al., 2003). Environmental factors have been shown in past literature to impact forage quality and beef calf performance (Krause et al., 2010; Kelln et al., 2011). The study site has been used in past corn grazing studies and biomass yields have been shown to fluctuate due to more favorable growing conditions and increased corn heat units in one yr compared to another. Temperature, wind chill and snow depth could also effect calf performance and study period length each year.

Past literature has discussed the potential of the two whole plant forage crops to cause digestive upset in cattle due to the starch component of grain kernels (Nagaraja and Titgemeyer, 2007; Jose, 2015). For this reason, calves were offered baled greenfeed for the first week of the trial to allow the rumen environment to gradually adjust to the new backgrounding diet. Whole plant forage was then only offered to calves by cross fencing 3 d allocations to minimize preferential selection of corn cobs and barley heads. The maturity of the barley crop was controlled by swathing at the late dough stage. The corn crop was left standing for the grazing trial so careful variety selection was the only option to minimize acidosis risk. By choosing a variety that was roughly 300 CHU's later than the corn heat unit area, the growing season of the corn crop was extended so that maturity would not pass 30-50% milk line before a killing frost occurred (DuPont Pioneer, 2016).

There were some challenges experienced during the current study involving fence system, calf behavior and wildlife. A proper evaluation of fencing systems used for the perimeter and cross sections during extensive winter grazing was extremely important.

Accumulated snow acted as an insulation, therefore limiting electric conductivity from the ground wire. In the first year of the current study, calves were placed in field paddocks later than planned and it was difficult to keep calves from going underneath the limiting fence due to poor electrical current. In the second year, calves were placed in field paddocks much earlier and were sufficiently trained to the electric fence, minimizing escape problems. A mature cow with winter grazing experience was also intermingled with each group of calves for the first week of the trial. The calves were able to learn from the cow how to access and utilize both swathed and standing whole plant forages. The interaction of wildlife with the forage crop and calf herd also provided some challenges to the study. Gophers and black birds predated on the corn crop during establishment and maturity, possibly decreasing biomass yield and forage quality. Deer also fed on the whole plant forages, but it was more problematic when they scared calves and caused the groups to break through perimeter and cross fences.

Following backgrounding steers were placed on feedlot finishing diets and there was no difference found in ADG and carcass characteristics between the steers backgrounded on either extensive grazing system or fed in drylot pen systems. Steers backgrounded on whole plant corn and fed a corn based feedlot finishing diet had higher HCW compared to steers finished on a barley based diet. However, there was no difference in final carcass scoring with 85% of steers receiving AAA and 63% of steers receiving a yield grade three class. There is evidence that due to compensatory gain, extensively backgrounded steers could achieve similar feedlot performance to drylot pen fed steers once the animals are placed on a feedlot finishing program.

In conclusion, low heat unit corn varieties can be considered by producers as alternative forage sources for grazing beef calves due to acceptable crop quality and biomass, while also reducing total system costs and having no negative effect on feedlot finishing performance.

7.0 References

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8.0 Appendices

8.1 Appendix A

Table A.1 Temperature and precipitation for Lanigan, SK over 2 yr						
Month	Temperature ¹			Precipitation ²		
	°C			mm		
	yr 1	yr 2	30-yr ³	yr 1	yr 2	30-yr ³
June	16.2	15.5	15.8	98.8	135.4	70.4
July	19.7	18.9	18.4	41.2	92.2	55.5
August	16.8	17.5	17.5	43.4	9.2	54.0
September	11.7	13.8	11.5	9.8	34.0	36.0
October	1.32	1.1	4.1	19.2	NA	23.0
November	-8.5	-8.0	-5.7	29.0	26.6	14.5
December	-17.7	-20.7	-12.8	17.2	28.2	16.8
January	-16.4	-17.0	-15.1	14.2	11.6	17.3
February	-12.5	-21.0	-12.0	26.4	NA	11.4
March	-13.3	-12.3	-5.3	22.6	NA	16.5

¹Obtained from Termuende Research Ranch Benchmark site weather station

²Obtained from environment Canada

³30-yr average from 1981-2010

Table A.2 Snowfall and windspeed for Lanigan, SK during backgrounding over 2 yr					
Month	Snowfall ¹			Wind Speed ²	
	cm			m/s	
	yr 1	yr 2	30-yr ³	yr 1	yr 2
October	0.0	0.0	6.1		5.8
November	15.0	5.0	14.4	5.8	5.4
December	24.0	23.0	16.3	4.1	5.0
January	24.0	23.0	17.3	4.0	8.0
February	24.0	NA	11.4	2.3	6.0
March	22.0	NA	15.3	2.4	5.5

¹Obtained from environment Canada; total snowfall on the ground

²Obtained from Termuende Research Ranch Benchmark site weather station

³30-yr average from 1981-2010

Table A.2 Accumulated corn heat units (CHU's) in each yr of backgrounding phase

	May 31	June 31	July 31	Aug 31	Sept 31	Oct 31	Total
Yr 1	135.8	554.1	779.3	658.4	436.2	16.7	2580.5
Yr 2	274.7	548.0	627.9	685.2	484.6	57.7	2678.1

Table A.3 Soil nutrient analysis over 2 yr

Item ¹	Year 1 (2012-2013)	Year 2 (2013-2014)	
	BAR*	COR*	BAR*
NO ₃ -N	70.2	136	70
P	21.8	74	65
K	1090	>1200	>1200
SO ₄ -S	>96	>96	>96

¹NO₃-N = Nitrogen; P = Phosphorous; K = Potassium; SO₄-S = Sulfur

*Previous crop type grown on soil sample area

Table A.4 Nutrient composition of supplemented range pellet

Item ¹	%, DM
DM	64.1
CP	16.1
NDF	25.8
ADF	13.1
TDN	72.0
NEg	0.49
Ca	0.82
P	0.49

¹DM=dry matter; CP=crude protein; ADF=acid detergent fibre; NDF=neutral detergent fibre; TDN=total digestible nutrients; NEg=net energy for gain; Ca=calcium; P=phosphorus.

8.2 Appendix B

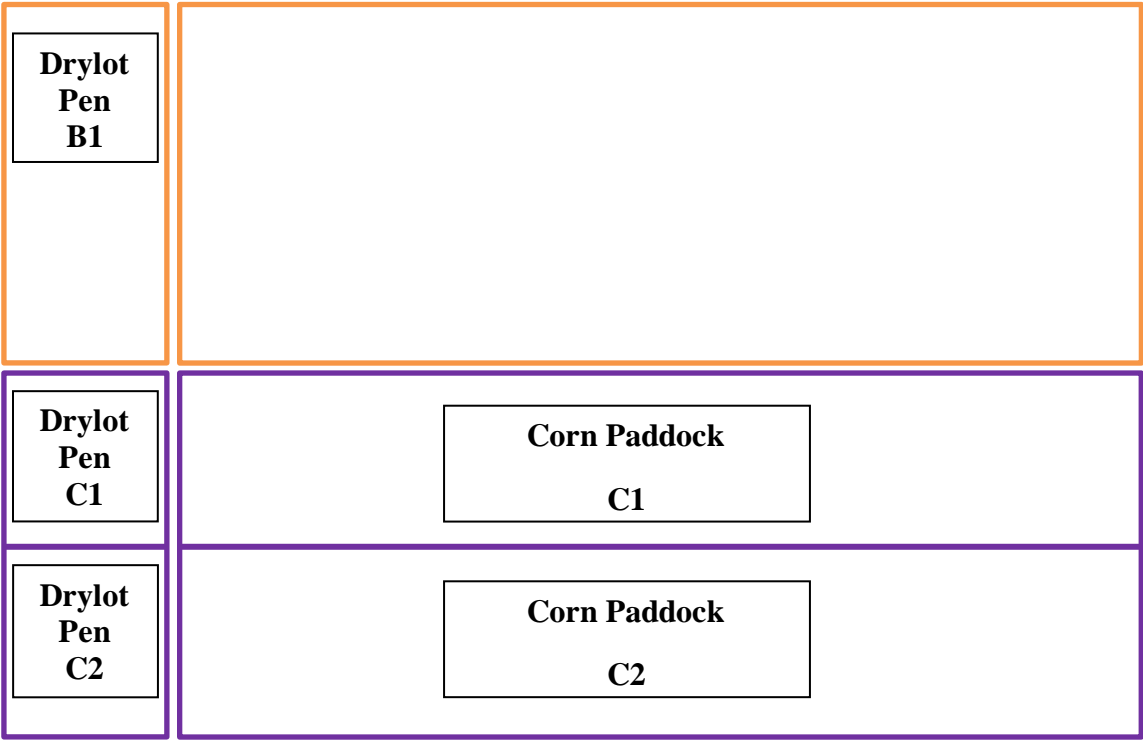


Figure B.1 Plot Diagram